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AGRICULTURAL SCIENCE
APPLIED
IN
PRACTICE

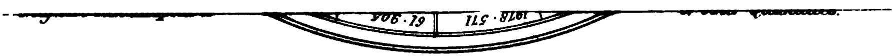
BY

W. WALLACE FYFE

AGRICULTURAL SCIENCE

APPLIED IN PRACTICE.

EXAMPLES. 1ST SET THE INDEX ON A GIVEN VALUE OF WHEAT SAY 45/. & THE PRICES OPPOSITE THE DESCRIPTIONS OF FOOD ON THE INDEX ARE THOSE WHICH THEY SHOULD COMMAND WHEAT BEING WORTH 45/ PER QUARTER OF 504 LBS. OR 5.625 PR BUSHEL OF 63LBS · 2ND BUTCHER MEAT IS NOT STATED ACCORDING TO ITS COMPARATIVE NUTRIMENT TO WHEAT BUT AT THE PRICE AT WHICH 14 LBS CAN BE RAISED WHEAT BEING AT A CERTAIN VALUE — THUS. WHEAT BEING AT 45 THE INDEX SHOWS BUTCHER MEAT TO BE WORTH 5.626 PR STONE OF 14LBS AND AT THAT PRICE WOULD ALLOW TO THE FARMER AT THE RATE OF 0/.842 FOR TURNIPS AND SO ON WITH THE PRODUCE ACCORDING TO THE VALUE STATED OPPOSITE EACH.



EXAMPLE. SET THE INDEX ON THE DESCRIPTION OF FOOD FOR WHICH THE EQUIVALENTS ARE REQUIRED, & OPPOSITE EACH DESCRIPTION ON THE INDEX WILL BE FOUND THE EQUIVALENTS,—THUS TO FIND THE EQUIVALENT OF 112 LBS. BEANS, SAY IN OATS, SET THE INDEX ON BEANS, & OPPOSITE "OATS" IN THE INDEX (TO THE RIGHT) WILL BE FOUND 134.340, & THE OTHER EQUIVALENTS ARE AT THE SAME TIME EXHIBITED. FOR INSTANCE. IT IS SEEN THAT 134.340 OF OATS IS EQUIVALENT TO 112. BEANS OR 108.348, BARLEY, OR 383.384. POTATOES, & VICE VERSA.

AGRICULTURAL SCIENCE
APPLIED IN PRACTICE,

FORMING AT ONCE A

TEXT BOOK AND CONCISE COURSE

OF

SCIENTIFIC AND PROGRESSIVE INSTRUCTION,

WITH QUESTIONS APPENDED TO EACH DIVISION; AND
TWO ENGRAVED ROTARY CALCULATING TABLES
OF FOOD EQUIVALENTS, FOR WEIGHT
AND VALUE.

BY

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Editor of the "Dorset County Chronicle."

LONDON:
GROOMBRIDGE AND SONS, 5, PATERNOSTER ROW.

MDCCCLIX.

DORCHESTER:

PRINTED AT THE COUNTY CHRONICLE OFFICE.

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THE THEORY.

THE PRACTICE.

PREFACE.

IMPRESSED with a conviction of the value and importance of Agricultural Instruction as a primary branch of practical education in ordinary Schools—and desirous of showing how easily, inexpensively, yet effectively it might be afforded, through the medium of instructions taking Practical along with Scientific considerations—the Author sought and found an opportunity of putting to the test the possibility of stimulating, in the first instance, Teachers and Normal Students to the task. He is now desirous to supply the possibility of generally carrying out the same attempt by means of a Text Book.

By imparting explanatory knowledge at School, where the total neglect of it has plunged the English, Irish, and even Scottish peasantry into lamentable indifference to the essential facts connected with their daily toil—it is only natural to anticipate that not they alone, but the classes who are required to sustain them in their indigence, and oft-recurring destitution, might be benefitted.

On this ground it is clear that THE UPPER CLASSES, whether Proprietors, Farmers, or other Ratepayers, are called upon to support all endeavours to introduce Elementary Education in Agriculture.

It is not only that, from the labourer being led to apprehend its exact objects, labour must be better performed; or that, from being more carefully attended to, production will be more amply increased; it is not merely because, along with the augmented produce of the soil, the comfort and condition of the producer will be improved; it is not solely on these grounds that education in the art of Agriculture assumes vast importance. With the diffusion of practical intelligence, commences a new era, in which the elementary knowledge imparted in Schools is destined to be carried out and applied to the business of life. This must elevate the tone of society at large; it must bring up enlightened information into close proximity with workmanship and skill; it must fit and provide a larger variety of individuals for those instinctive struggles, by which men advance themselves on the strength of their attainments.

ALL CLASSES are therefore interested in supporting this object.

Having experienced all the success anticipated, within the limits to which his experiment has yet been pushed, the Author is willing to place these outlines at the disposal of any who may be desirous of following up the same course, *i.e.* by repetition of them, as Lectures, in whole or in sections. They are necessarily offered, however, as mere examples or illustrations of an indefinitely extended course, which *might* be modelled on the same principle of blending scientific with practical instruction. But it may be mentioned, that, taken as hints for study, the present outlines present a connected view of the leading sciences applied in Agriculture; indicate the best mode of mastering agricultural knowledge, as contrasted with the methods generally pursued at home and abroad; and, passing to practical points, discuss the chief operations of husbandry—the early and subsequent treatment of plants, animals, manures, &c.—and finally describe their comparative results and values, so that a skeleton course of Agriculture is here provided.

High West Street, Dorchester,
March, 1859.

LECTURES ON AGRICULTURE.

DIVISION I.

STUDY AND APPLICATION OF THE SCIENCES IN AGRICULTURE.

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Some account of the Schools of Agriculture.

§ 1. Agriculture, however old as an art, is comparatively new as a science. And to the question, "what can education do for agriculture?" we must therefore naturally answer—everything. Until of comparatively late years, education, in *that* sense in which we now understand those intelligent systems which, by the hand of a careful constructor, mould within the receptacle of the mind a well arranged storehouse of special information, had done nothing to propagate a knowledge of the cultivation of the soil. Man, trusting to the earth's fertility, to the promised and unfailing recurrence of the seasons, "of summer and winter, seed time and harvest," went through the routine duties of husbandry, taught him by tradition, and slowly and partially matured by experience, attributing to chance, and regarding as a "mystery" results or failures into which he never troubled himself to examine. The physical sciences, almost all of which bear intimately upon agriculture, because *it* deals with the life and death of matter, were, for ages, disregarded in education and in schools; when at length the modern sciences made their appearance, it was generally in close connection with the other arts, or in pursuit of some great discoveries that they were prosecuted, and the practical agriculturist who knew nothing of them, did not believe that they could have any bearing on his case. He long and obstinately repudiated the notion that he could be benefitted by book farming, and he still does this to a very great extent. Even now that the advantages of scientific knowledge have rushed in upon him, not from one but from numerous distinct sources, he has been well described as regarding it in the light of a newly advertised manure, of which he has only to purchase a specified quantity, and apply it to his farm! But what can we say to the farmer, when we find an authority insisting, not more than 30 or 40 years back, that disquisitions concerning the food of plants, and even concerning the principles of vegetation, are quite foreign to agriculture, and that by such means farmers will inevitably be ruined and made miserable.

§ 2. As it may be fearlessly asserted that there is no science more capable of benefitting by the progress of physical discovery than agriculture, it follows that there is a pressing necessity for bringing up the cultivator of the soil to the level of the intelligence of the age, of communicating to him facts and knowledge expressly applicable to his purpose. Nor is it difficult to see how immediately allied to the pursuits and duties of the agriculturist are the advantages of scientific and practical instruction.

§ 3. A census expanding at a ratio to which no authentic record of any former period of human history can furnish an equivalent—since it simply follows out the progress of multiplication, has been steadily advancing from the number of six parents, at the period of the Deluge, to from 800 to 1,000 millions constituting the present population of the earth. In our own country, according to the last census, we have 27,600,000 of a population. And a population in what condition? Wealth, doubtless, rolls in its gilded chariot, and grandeur emblazens the great man's gate; but the roll of the chariot wheel is drowned in shouts of ignorance, blended with shrieks of destitution, arising from the very streets over which it rattles, whilst the escutcheon over the gate of affluence grows dim beside the squalor of the Crofter's cabin. Does it not, therefore, appear that Providence intended the gifts of knowledge which are the peculiar glory of our period to compete with the social evils which are its shame?

§ 4. Man is destined to multiply; not to exhaust, but to replenish the earth. And there is upon the face of that earth abundance of uncultivated soil to feed all the future generations that any arithmetical or even geometrical progression of their numbers is ever likely to produce. The empire of China, containing about a third of the human race, is supposed to be cultivated to its limits. But China has 640 millions of acres capable of cultivation; rice is the natural food of the people, and an acre of rice will supply from five to ten persons with subsistence, so that even by their present mode of cultivation, which is not perhaps the most scientific, China alone could maintain from three to six thousand millions of people, from three to six times the existing number of the entire human family! In the *Edinburgh New Philosophical Journal* for September, 1828, it was estimated that the United Kingdom contained 74,000,000 of acres, 64,000,000 of which are susceptible of cultivation. One acre of arable land will yield food enough for a horse, and half-an-acre for a man—how many therefore would our own islands maintain?—apportioning the produce proportionally amongst men and horses, they would thus support 120 millions of people and four millions of beasts. But suppose there are, as estimated by a distinguished agriculturist some years ago in the ***Mark-lane Express***, thirty-three millions of acres capable of cultivation in England, nine in Scotland, and sixteen in Ireland, in all, fifty-eight millions, and that whilst every acre would support a complete family on vegetable diet—to yield both flesh and vegetable diet in abundance, it might require three acres. Why, then, the United Kingdom alone would at this rate support 300 millions on vegetable diet, or 100 millions, just a tenth part of the whole race of Adam, on flesh and vegetables. But more than this—and without at all aspiring to support a tenth of mankind on the face of this little island, it can be shown that by drainage alone, a large superfluity of British corn could be raised. This is your work gentlemen; it is towards some such consummation that you have to contribute your efforts. I require you to go forward with the attempt. Be assured that as no produce so far as can be perceived is ever raised by man beyond what is requisite for the supply of his immediate wants—be assured that as he obtains but what he is instructed to ask of God in his prayers, and that only as God permits him to ask it—day by day his daily bread—it is the task of those who undertake to train men in their duties, sacred or secular, to cultivate the means whereby that provision may be rendered available to them, in accordance with the precise conditions of the grant. If, therefore, we see population in any corner of these dominions languishing in helpless and deplorable ignorance, and "perishing" from destitution, springing emphatically from "lack of knowledge," can we doubt that on our heads rests the responsibility we undertook to teach, and what have we taught? We have not addressed ourselves to one of the most natural, the most necessary, and the most incumbent parts of man's efforts—we have not taught him to fulfil his destiny, which is "to earn his bread in the sweat of his brow." To leave no loophole open for doubting our national resources, for banishing calamity by the help of proper instruction, I will endeavour to show what that instruction might consist. But having developed briefly the extent to which British cultivation is capable of being pushed, I would ask you in your own minds to reconcile the facts of such visible abundance with the existence of our pauperism, destitution, and crime, whether in town or country.

§ 5. If due attention were given to industrial education no such things as pauperism, destitution, or crime could exist. We should have poor it is true, "The poor ye will always have with you"—but they would be the aged, the infirm, the sick, or the maimed—they would not be able-bodied paupers, the disgrace of our intelligent age, of our hospitable clime, and of our national spirit. We should also have criminals; but they would be real ones—not criminals whose excuse deprives punishment of half its sting, and suspends the scourge of justice in the pitying hands of authority.

§ 6. The question of what agriculture has yet to accomplish in this country, largely stated, is just this: The amount of produce which we raise must be driven onwards to the amount which we could raise. Bearing in mind that, so far as past experience goes, we will never raise more than we economically require, we must essay to redeem the needless destitution of the land, by undertaking to raise an adequate supply of subsistences.

§ 7. Now the area of our islands amounts to 74,394,433 acres, according to Mr. Cowling's survey (of 1827) quoted in "*Porter's Progress of the Nation*"—since which time, considering the quantity of land that has gone out of cultivation in Ireland and the Highlands of Scotland, whilst reclamation has also been fast proceeding, we are not warranted in assuming any great alteration in the figures, and, therefore, we may take one-fifth of the surface as waste and four-fifths as cultivatable as then stated—thus

	Acres cultivated.	Acres uncultivated but improvable.	Acres unprofitable.
England ...	25,632,000	3,454,000	3,256,400
Wales ...	3,117,000	530,000	1,105,000
Scotland ...	5,265,000	5,950,000	8,523,930
Ireland ...	12,125,280	4,900,000	2,416,664
Islands ...	383,690	166,000	569,469
	46,522,970	15,000,000	15,871,463

§ 8. It is proper to state how the acreage in actual cultivation is distributed by Mr. Cowling, although we shall immediately direct attention to a much more recent estimate: In—

		Arable and Gardens.		Meadows, Pastures, and Marshes.	
England	he gives of	10,252,800	stat. acres and	15,399,200	acrs.
Wales	„	890,570	„	2,226,430	„
Scotland	„	2,493,950	„	2,771,050	„
Ireland	„	5,389,040	„	6,736,240	„
Islands	„	109,630	„	274,060	„
		19,135,990		27,386,980	

§ 9. Perhaps the most recent authority, *Macqueen's Statistics of* 1850, taking the area of the United Kingdom to be 77,394,433 acres, regards cultivation and waste as thus distributed:—

5,500,000	acres are under Wheat
3,500,000	„ „ Barley
7,000,000	„ „ Oats
3,500,000	„ „ Potatoes
19,500,000	
1,600,000	Acres are under Gardens and Orchards
2,000,000	Turnips
9,000,000	Hay, Clover, and Meadow
17,600,000	Best Pasture
3,900,000	Sundries and Fallow
13,400,000	Grazings or natural pasture
8,894,433	Rivers, lakes, and in a state of nature
1,280,000	Forests, copses, trees
100,000	Hops, flax, hemp, &c.
77,394,433	

§ 10. Suppose we could cultivate 61,522,970 acres to the full extent, as means of human support, we should be able to sustain a population of 184,568,910 individuals, allowing three human beings to the acre. As it is, despite the supplemental aid of extensive importations of corn, still we have people starving; yet we nevertheless support upwards of two millions of horses, consuming thirty-three million quarters of oats; and if it be true that each horse consumes the food of eight men, we could at this moment feed instead of horses, from our corn produce, a surplus population of sixteen millions—but say twelve millions of effective men; and should the reaping machine, steam plough, and other applications of machinery succeed, it is not easy to say how speedily a large proportion of this may become available for human food by dispensing largely with draught animals as to some extent a proportion has already done so by the opening of railways, occasioning a diminution of the number of horses employed in the country. We may think it strange; but so would the ancients have thought if told that a couple of these same horses used by them exclusively in war, would one day be employed to do several times the work of a huge team of bullocks.

§ 11. Such being the field on which our agriculture has to labour, we are next to inquire what aid it is destined to derive from science or education?

§ 12. Agriculture is an applied science, at least it is an application of the sciences to the production of the fruits of the earth. It is, however, a great mistake to conceive that scientific agriculture involves complete study of the sciences so applied. The teacher of agriculture should rather endeavour to avail himself of the researches made on his behalf, than to consume his time in testing the truth of scientific discoveries.* Mr. Bree, an agreeable and enthusiastic writer on agricultural chemistry, says it is unnecessary that the farmer should have an intimate acquaintance with it. The knowledge he requires is the means of applying the discoveries of others to the improvement of his system of farming. The chemist can explain that certain plants require certain food; and though the statement is founded on a knowledge of the elementary structure of both, it does not follow that the farmer should understand the analysis of wheat or stable manure. Mr. Solly, another popular author on agricultural chemistry, has also found it necessary to state that the chemistry which may benefit the agriculturist is neither philosophical chemistry nor the chemistry of the laboratory; but it is what may be termed the chemistry of nature—if those simple and elementary rules which

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* It was well said by Professor Johnson, in his advertisement to the 29th edition of his Wonderful Catechism, with exception of Stephens, the only elementary class book yet known devoted to this great branch of practical instruction, and as such circulated throughout the schools not only of this country and America, but of Germany, Holland, Flanders, Italy, Sweden, and Poland, "that it is not chemistry or geology but scientific agriculture that is to be taught. Yet this very catechism is one of "agricultural chemistry and geology," and is so intituled.

affect the ordinary operations either of nature or art are all going on before us, such knowledge is useful to every one, and sooner or later its value will become apparent. It is by neglecting the plain common sense views which these writers gained by their experience in endeavouring to give agricultural chemistry a popular turn that the attempt to dove-tail its simple results amongst the facts of education has been frustrated and rendered abortive. We may discover experimentally what are the affinities to be studied. Each plant is composed of an organic part that burns away in fire, and of an inorganic or mineral part which does not burn away. Burn any plant, a bit of straw or wood in the flame of a candle, while the larger part burns away, a smaller part, the ash, does not burn away; heat a portion of soil to redness on a slip of sheet iron or the point of a knife, the soil will first turn black or carbonaceous, afterwards grey, brown or reddish as the blackened organic matter burns away. The strong affinity evinced between the organic and inorganic constituents of the plant and the animal, it is, that gives us the control over the manufacture of meat from vegetation. Burn a morsel of skin, nail, flesh, bone, hair, or cheese in either of the above ways, and when all the black matter at first produced is consumed, a portion of incombustible ash remains behind. Now what proportions of inorganic or mineral matters do the parts of plant, soil, and animal substances respectively contain and leave when burned? 100 lbs of dry wood seldom leaves more than half a pound of ash; of dry wheat or Indian corn less than 2 lb.; dry straw 5 or 6 lb.; dry hay 8 or 9 lb.; and the leaf generally contains more mineral matters than the other parts of plants, as proved by tobacco giving 16 to 20 lb. of ash for every 100 lb. of dry leaf. In regard to soils, although we should generally find it requisite to gain a knowledge of each individual soil by special analysis, it may be advantageous to be generally aware that peaty soils sometimes contain as much as 60 or 70 per cent. of vegetable matter, whilst few of the richest alluvial soils contain more than ten, or more commonly 5 or 6 per cent. of organic matter, the rest being mineral or inorganic to the average extent of from 90 to 98 per cent. In the same way the soft parts of the animal, as flesh, skin, and hair, leave only 5 per cent., while the hard parts as the bones leave from 50 to 60 per cent. of inorganic matter. Thus the plant deriving its mineral matter from the soil, and its organic from the soil and air, has much organic and little mineral matter.

§ 13. The roll of the sciences applied in agriculture, opens up a range so wide as literally to compel acceptance of their ascertained facts, instead of minute philosophical study. We have not only chemistry on the list but we have geology, vegetable physiology, botany, zoology, animal physiology, meteorology, hydrostatics, pneumatics, mechanics, and the applied science of agriculture proper. Of these several sciences, chemistry would inevitably first come into play. The art of fertilizing the soil belongs to it. The chemical theory of manure was that which first developed itself by slow experimental processes to the eyes of the old farmer, till he was astounded to find that all it had cost him—the labour of a lifetime—to ascertain, by "experience," the chemist could have told him in an instant. "It is scarcely possible," says Sir Humphrey Davy, "to enter upon any investigation in agriculture without finding it connected, more or less, with doctrines or elucidations derived from chemistry." And with chemistry accordingly he began. In chalking out, however, the natural cycle of the agricultural sciences, a mere outline of the relations of the more elementary of them proves conclusively the necessity of taking up merely their ascertained truths.

I. GEOLOGY.

§ 14. The aid of geology is first required to group and classify the varieties of soils, to tell us of their derivation from those several formations of which the crust of the earth is composed, their peculiar depth, their relative positions in succession to one another, and the natural influences of the rocks that underlie them. The importance of this is expressly illustrated by an attentive examination of the soils of any district. Take for example any county, which, in its mineral as in its arable tracts, we will find composed of two surface soils; the one rising up through and spreading over the various beds of rock composing say coal measures, and the other say clayey deposits—debris formed from two classes of rock, having gradually crumbled down and formed distinct soils—the shales and sands of the coal measures produce cold clays, hungry sands, or unproductive stoney gravels, the alluvial and diluvial deposits richer tracts. Common sense at once declares these to require very different modes of culture and treatment. To geological causes alone, therefore, is it owing that one region of a country is fitted to become the abode of a busy, thriving, and happy agricultural population, whose fields adorned "with waving wood and golden grain," supply not only themselves, but the artizan hives of the bustling city with the necessaries of life; whilst other districts again are exclusively of a pastoral character, or thinly populated, except with the fleecy people of the wolds, whose flesh and wool yield sustenance in another form. Thus the older formations yield clothing and animal food; the newer deposits rich agricultural produce. But do not these arrangements conduce to the proper distribution of society and of wealth, and to that diversity of employment, as of habits of thought and expression, on which, even so early as the building of the tower upon the plain of Shinar, the felicity and advancement of the human family were felt to depend? Yet it frequently happens that there is a diversity of soils on the same farm, and a knowledge of the qualities of soils thus becomes of the greatest consequence to the farmer who must select the rotation of crops best adapted for the soil of his farm. It is unreasonable to expect poor light land to produce wheat and beans, although these may certainly be forced by high cultivation, just as Mr. Huxtable engaged to grow a hybrid turnip on a mahogany table, and *did* grow one on a deal board. Rye, oats, and roots, such as potatoes and turnips, will yield a better profit on such soil, by being raised at less expense; whilst valuable crops, even when forced with specifics, are at best precarious when tried on soils unsuited to their growth. In moderately good loam, wheat, for instance, recurs with advantage every fourth or fifth year, whereas in rich compact loams it may, with facility, be reared every third. Clover and the artificial grasses again cannot be greatly depended upon oftener than every sixth year; nor should flax and, it has been said, potatoes, be planted oftener than this on the same spot, notwithstanding the potato profits of the system of high farming.

§ 15. Thus whilst geology gives directions for the distribution, and, to some extent, for the treatment of crops, being itself a compound science, in which chemistry has a large concern; in alliance with the latter, it makes a yet more minute investigation into the character of the disintegrated materials and decayed vegetable matter, or humus, of which soils are composed. The humus is the great medium through which carbonic acid is evolved and transmitted to the roots of young plants; but the other qualities of a soil depend, in a great measure, on its capacity for admission of the proper quantity of air and moisture, without which the decomposition of animal and vegetable matter, furnishing the carbonic acid and ammonia required by plants, could not occur.

§ 16. The general ingredients of soil are clay, sand, and lime. Almost all rocks are composed of these ingredients, and supply them to soils by their decomposition. Upon the proper admixture of these in the formation of soil depends its fertility; when these substances exist in undue proportion, an inferior soil is the result.

§ 17. In Sprengel's Analysis of Soils we find :—

		Fertile.	*Barren.*
1	Silica with fine Siliceous Sand	64.800	—
	Silica with coarse Siliceous Sand	—	95.778
2	Alumina	5.700	0.320
3	Peroxide of Iron	6.100	0.400
4	Peroxide of Manganese	0.090	trace
5	Lime	5.880	0.286
6	Magnesia	0.840	0.060
7	Potash	0.210	trace
8	Soda	0.393	0.036
9	Phosphoric Acid	0.430	trace
10	Sulphuric Acid	0.210	trace
11	Chlorine	0.201	0.052
12	Carbonic acid combined with Lime	3.920	trace
13	Humus	5.600	0.998
14	Nitrogenised matter	1.582	—
15	Water	1.504	not deter.
		97.460	97.930

Here we perceive that the constituents in which the barren soil is deficient, form just the inorganic constituents essential to the cultivation of plants.

§ 18. Silica they both possess largely, though in different states of solubility, the barren soil possessing it almost to the exclusion of aught besides. Now, the action of silica is mechanical; it gives to soils openness and porosity, and for that purpose sand is not unfrequently required to sharpen stiff clay lands. It has certainly, in addition, the property of forming combinations with the ingredients more important to the plant —viz. the lime, potash, soda, &c., existing in appreciable proportion in the fertile, but scarcely traceable in the b[illegible] grains the chief consti- [illegible] predominate; therefore we [illegible] which retains no moisture, and if manured, decomposes the manure too rapidly, emitting the ammonia and carbonic acid back into the air ere the roots have time to form their fibres.

§ 19. Alumina or clay again, devoid of quartz grains or sand, becomes baked into a hard paste, excluding the air, and once wet, retaining the water with which it is saturated so as to prevent the further supply, and thus the decomposition of animal and vegetable matter in the soil is stopped, and the carbonic acid and ammonia contained in every new supply of rain water precluded from yielding nutritive supplies to the roots. Common clay, compounded of about sixty parts of silica and forty of alumina is considered as the highest stage in the decomposition of rocks. Access being thus afforded to the ammoniacal and other gases, alumina, like charcoal, possesses the valuable property of fixing them and holding them in retention for vegetable nutrition—a power held to be increased by the alumina being calcined—hence top dressings of burnt clay are employed that the ammonia of rain water may be caught and preserved for the use of the spongioles at the roots of the plant, by which it imbibes nourishment. Besides all this, alumina, though chiefly valuable in conferring upon soils their plasticity, whereby growing plants are sustained in a settled position in the soil, is of further importance from being chiefly derived from minerals which supply the potash and other substances entering into the composition of the ashes of plants. This gives it value in combination with lime; for when lime is added to clay its valuable alkalis are liberated in a soluble state. "It is obvious," says Liebig, "that mixtures of clay and lime contain all the conditions necessary for the liberation of the silicate of alumina, and for rendering soluble the alkaline silicates." Sir Lyon Playfair, and Professor Johnston, the disciples of Liebig in this country, fully endorsed this doctrine.

§ 20. Before adverting to that important constituent, lime, we would direct attention to another existing in equal or greater quantity in Sprengel's fertile soil—of peroxide of iron, of which Sprengel's fertile soil shows 6 per cent. We must be careful to distinguish betwixt the peroxide of iron and the protoxide, also a general constituent of subsoils. These colouring matters of ferruginous soils and subsoils are both of them insoluble in water; both are also remarkable for the facility with which they combine with oxygen, a process whereby the protoxide, which is most injurious to vegetation, on being turned up to the surface by the subsoil plough, although it causes the land, for a time, to lose its fertility, becomes converted into the red peroxide by the action of the oxygen in the atmosphere, and in that state exerts a favourable instead of an unfavourable influence on vegetable life, restoring the productiveness of the soil more vigorously than before. Peroxide, which exists in all soils in greater or less abundance, enters into the composition of the ash of plants, and also performs certain functions in the decomposition of organic matter, for, like alumina, it absorbs ammonia admirably. An irresistible inference in favour of deep ploughing, deep draining, and any other admission of free atmospheric air into the soil at once suggests itself, therefore, from the circumstance of the proto-oxide being convertible into the peroxide by an additional supply of oxygen. But even the peroxide in great excess deteriorates the quality of soils, and from this cause ferruginous soils are too frequently found to be barren.

21. Lime, however, is of insuperable importance in soils. It is an alkaline earth, forming an essential organic constituent of every cultivated vegetable. It exists in soils combined with acids, sulphuric, nitric, but more especially carbonic acid—that gas which you find driven off by heat in the lime kiln, leaving quick or caustic lime behind in an uncombined condition, soluble in water, and consequently fit for manure, but so readily does quick-lime recombine with the carbonic acid of the atmosphere, that by lengthened exposure it would again

become carbonate of lime, as unfit for manure as the kindred and almost identical substances, chalk, marble, or limestone. The office performed by lime in the soil is that of decomposing silicates and rendering them available as inorganic food for plants by combining with itself a portion of their silicic acid, so as to form silicate of lime. In this manner the alkalis, potash and soda, are liberated as soluble silicates. In the same manner, when added to clay, its alkalis are liberated in a soluble state by the lime.

§ 22. These facts, perhaps, sufficiently exemplify the characteristics of the chief materials of soils, of which it is the business of geology to determine the distribution: for all soils have been formed by the crumbling or disintegration of rocks, however hard and refractory some of the latter may appear. Chemical and mechanical agents accomplish the process of decomposition. The rock moulders away under the slow but incessant attacks of the oxygen, carbonic acid, and water of the atmosphere; and the plants which begin to appear on the shallow debris, die and contribute to the mineral accumulations small quantities of vegetable or carbonaceous matter. The mechanical forces existing for destruction of the coherence of rocky particles are powerfully exemplified in the expansion during frost of water lodged in a crevice. Water in the form of ice increases in bulk with an expansive force of tremendous energy. In the severe winter of North America, above the latitude of 31 deg., where brandy congeals and the lakes freeze eight feet in thickness, rocks split asunder in the frost with the noise of artillery, and their shattered fragments are precipitated to considerable distances. In speaking of rocks it is proper to observe, however, that the term in geology applies to every formation, be it loose sand, gravel, clay, or hard compact granite. The land in the vicinity of Mount Vesuvius is said to be extremely fertile. The soil, entirely formed from disintegrated lavas and cinders, can contain little *humus* or decomposed vegetable matter. Yet on the volcanic ashes being exposed to the influence of air and moisture, a soil is formed in which plants grow luxuriantly. The reason is that the alkaline substances contained in the ashes on being exposed to the weather become dissolved in the moisture absorbed by the spongioles at the roots of the plants.

§ 23. To determine the quantity of potash in a soil whence grain crops are to be taken becomes a matter of infinite consequence to the farmer. Wheat stalks, for instance, yield 15½ per cent. of ashes, barley straw 8½ per cent., and oats only 4·10; a field capable of supplying one crop of wheat with the necessary amount of potash will thus be able to raise two crops of barley and three of oats. Felspar is the mineral whence clays containing potash, soda, &c., are derived. It is a chief ingredient in all granites, gneiss, mica slate, porphyry, clay slate, grauwacke, sandstone, and the volcanic products, basalt, clinkstone, greenstone, and the various kinds of lavas. It contains 64 per cent. of silica the basis of quartz, 18 per cent. of alumina the basis of pure clay, 13 per cent. of potash, and 3 per cent. of lime. According to Liebeg an acre of land, Hessian measure, or 40,000 square feet if covered, 20 inches deep with the debris of

Felspar	would contain	1,500,000 lbs. of potash.
Clinkstone	from	200,000 to 400,000
Basalt	from	47,000 to 75,000
Clayslate	from	100,000 to 200,000
Loam	from	78,000 to 700,000

And the same illustrious authority states that a single cubic foot of felspar is sufficient to supply a wood, covering 40,000 square feet of surface, with the potash requisite for five years vegetation, and that a hundred thousandth part of loam mixed with the *débris* of the new red sandstone and some of the other secondary rocks, will suffice to supply a forest with potash for 1,000 years.

§ 24. The whole of the materials which form the outer surface of the crust of the globe are in a state of perpetual change. Every mass of solid matter, at or near the surface of the earth, is subjected to a process of degradation and dissolution. The stability of the "everlasting hills" is only relative to man's recorded time. The materials of which they are composed are being constantly transferred by the incessant energy of the ever-working agencies that surround them to the valley and to the river; and ultimately, it may be, to the deepest beds of ocean. But the working of those agents is of such a nature that we are made sensible of their power only as we are made aware of the operation of many other agents that surround us—by observing the effects that they produce. A great portion of the surface of the earth which is at present dry land, and therefore subject to our observation, is found to be composed of matter which bears the clearest and most unquestionable evidence of having first been reduced to the smallest fragments, or brought into a state of minute division—of having been subsequently transported by water from the "spot of earth" which had once formed its resting place, and of having been deposited where we now find it, layer upon layer, to the depth of many hundred, often of many thousand yards. Nor did the "living things" which found a habitation in those ancient waters escape the general doom: their remains, entombed in the sand and clay which have since become solid rock, have found a more lasting monument than Egypt's kings.

§ 25. The slow-working but powerful agencies by which those mighty effects were produced are still in operation. And they are agencies which the agriculturist may turn to his advantage. In his operations, as in those generally by which mankind have been able to extend their dominion over the material universe, he will find the most efficient aid by making himself acquainted with the natural agents that can be made to work in his favour, and by bringing their powers to bear for effecting his purposes. That portion of the earth's surface which is denominated the soil, and to which man and all living creatures are indebted for the means of subsistence, has been brought into the state of disintegration and comminution in which we find it chiefly by the operations of two agents—air and water—largely aided, more especially in certain stages of the progress of the work, by a third and scarcely less powerful agent, namely, the vital principle of plants.

§ 26. A piece of granite rock may remain for an indefinite length of time without any change, if it is buried to a certain depth below the earth's surface; but bring it to, or near the surface of the ground, and it is immediately attacked by the agents now referred to. The oxygen of the atmosphere unites with the iron which it contains, and alters its character and the space which it occupies. The cohesion of the solid mass is thus interfered with. The force which held its particles together is overpowered by the insiduous operations of a new agent that has been introduced; and one of the elements that aided in binding them in one solid body now tends to their disruption. This process may often be very distinctly observed in a mass of ferruginous syenite which has been for a considerable time fully exposed to the action of the atmosphere: the natural blue or lead colour of the rock will be found changed for some inches inwards from the surface into a redish brown colour, that is, into the colour of the peroxide of iron which the gradually penetrating oxygen has formed. The felspar of the granite is likewise extremely liable to decomposition. Wherever its crystals are exposed to the atmosphere they gradually become paler in colour and softer in texture, and ultimately fall down in the form of a white earthy powder. The potash, of which felspar contains from 11 to 14 per cent., unites with a portion of silica, and forms soluble silicate of potash. Two substances essential to the growth of vegetables—especially to the formation of the stems of grains and cereal plants—are thus brought into a condition suitable for being absorbed by their roots. And such is the beautiful arrangement in the chemistry of nature by which matter apparently so obdurate and intractable as that of flint, finds its way into the finest rootlets and the minutest spongioles of the vegetable kingdom.

§ 27. Nor is the action of water, in this part of the world at least, less incessant or less effective in contributing, by its mechanical force and by its power as a general solvent, to the breaking up, and the transporting from place to place, of the solid matter of the earth's surface. Wherever a soluble compound is formed, it is ready to wash it away, and thus expose a new surface for further change. Its mechanical power is exerted wherever it is in motion; whether impelled by wind against the weather-beaten surfaces exposed to its action, or rolled forward in the current whose weight and accumulated force no obstacle can withstand. But in this part of the earth, as in all high latitudes, it has an additional mechanical power communicated to it, which is in an especial manner effective in producing disintegration of solid matter, and consequently, in the formation of soils, as already noticed. Water, when exposed to a freezing temperature, passes from the liquid into the solid form, and in that form, namely as ice, it requires more space to contain it than it requires in the liquid condition. The expansive force which it exerts in passing from the one condition to the other is such as no attraction of gravity or cohesion can resist. Into whatever confined situation, therefore, the smallest part ticle of water has insinuated itself—into the minutes crevice of rock, or under the scales of oxide of iron formed on its surface—it there, when overtaken by a freezing temperature, exerts a disruptive force which no solid matter on earth is competent to withstand. The most careless observer cannot have failed to remark, after a severe frost, the extensive effects produced by the operation of this agency.

§ 28. The solid matter of the earth is acted upon in various ways by the vegetables which it nourishes. Their roots have undoubtedly a direct and immediate action, mechanical and chemical; but their power in the reduction of solid matter is principally exerted indirectly by means of the carbonic acid which they produce. Wherever plants establish themselves, however low their forms may be—the softest fungus, or the minutest lichen—a certain amount of carbonaceous matter, obtained from the atmosphere, is formed by their decay. Thus we have the origin of *humus*, or vegetable mould. This carbonaceous matter has the property of retaining in its pores and maintaining around in an atmosphere of carbonic acid gas, either formed by the union of a portion of the deposited carbon with oxygen, or attracted from the supply of carbonic acid at all times existing in the atmosphere. Rain, falling upon and passing through such carbonaceous matter, becomes abundantly charged with carbonic acid—becomes, in fact, acidulated water. Such water is a ready and active solvent of many substances that are not soluble in pure water; or in other words, the carbonic acid gas, with which the water is charged, unites with certain substances, previously insoluble, and forms with them a compound, or carbonate, which is soluble in water. And, even where no such combination takes place, the water charged with carbonic acid is capable of dissolving and holding in solution substances on which, apart from the acid, it would exert little or no action. Phosphate of lime, or bone earth, for instance, is insoluble in water, but it is gradually dissolved by water charged with carbonic acid. Carbonate of lime (limestone, or lime in the state in which it usually exists in the soil), is sparingly soluble in water; but it is dissolved by carbonic acid in excess. Thus we find that the plant itself produces the chemical re-agent by which its food is extracted from the solid rock.

II.—CHEMISTRY.

§ 29. Chemistry, according to our order of marshalling the sciences auxiliary to agriculture, comes next, although it is extremely doubtful whether it would not be more appropriate, after having investigated the properties of the soil, to turn to those of the plant, as developed in the sciences of vegetable physiology and botany; the chemical analysis of plants, however, may securely follow up their relation to the soil,

§ 30. To cultivate a plant, rear an animal, or treat a soil scientifically, we can conceive of nothing more essential to be known than its constituents. The constituents of plants, animals, or soils, are either organic or inorganic.

§ 31. The organic constituents of plants are resolved into four gaseous or chemical elements, viz., oxygen, hydrogen, carbon, and nitrogen. The three first compose woody fibre (called Lignine), gum, starch, and sugar. But there are others, termed the *nitrogenised* constituents of plants, into the composition of which all these four gaseous elements enter, together with minute portions of sulphur and phosphorus. The nature of these gases I am not going to define at any length. Suffice it that—

§ 32. Oxygen, the most abundant element in nature, constitutes one-fifth of the volume of the atmosphere, eight-ninths of the weight of water, and one-third that of the total weight of the earth's crust, and is what supports combustion and respiration.

§ 33. Hydrogen constitutes the remaining ninth of the weight of water, but is not found in the mineral kingdom.

§ 34. Carbonic acid is an important constituent of plants, and constitutes 40 or 50 per cent. of the weight of all kinds cultivated for food. The carbon whence it is derived is seen in the form of wood charcoal, soot, &c., its power of absorbing gases is most remarkable, Saussure proved experimentally that a cubic inch of boxwood charcoal absorbs 90 cubic inches ammoniacal gas, and 35 cubic inches of carbonic acid gas. One of the most valuable applications of this fact, is to be found in the use of peat charcoal as a fixer of ammonia.

§ 35. Nitrogen forms four-fifths of the volume of the atmosphere. In combination with oxygen it constitutes that great fertilising influence, ammonia.

§ 36. Now the question for us is, what are the sources of the carbon, nitrogen, hydrogen, and oxygen present in plants? It is essential we should discover this for plants being destitute of locomotion it is important to their culture to know how and in what state these nutritive elements must be supplied to them. Chemistry has here experimented for us. Van Helmont dried a quantity of soil, weighed it, and placed it in a box, in which he planted a willow; for twelve years he moistened the willow with distilled water, and at the end of that period found that whilst the tree had gained in weight 70lb., the soil had lost only 2 oz. Van Helmont hence supposed that water alone was the true food of plants. Subsequent investigators, however, have found that his experiments establish a very different thing—namely, that plants derive nearly all their nourishment from the atmosphere—as illustrated by the air-suspended plants of the Botanical Gardens—one of which I may mention, a "Ficus Australis," has lived for more than twenty years exclusively on water and atmospheric air. It is clear, at all events, that the soil yields up but a minute amount of the vegetable constituents. But if largely derived from the carbonic acid of the atmosphere, how are we to reconcile the amount of produce realised with the fact that this gas forms but a thousandth part of the weight of the atmosphere? Trifling as this amount may seem, Liebig calculates, however, that the aggregate quantity of it amounts to 3085 billions of pounds, and is thus quite adequate for the supply of vegetable sustenance. But the plant, absorbing the carbonic acid of the atmosphere, retains the carbon to build up its own frame and give it a certain resistance to destructability, whilst it again gives off the oxygen to the atmosphere. Animals invert that process, retaining a portion of the oxygen from the atmosphere, and giving off again the carbonic acid. Thus the supply is perpetually balanced; from the same aeriform compound that floats above and around us the same Almighty wisdom has provided opposite kinds of vital air; for the two great divisions of nature, the vegetable and animal kingdom, He has counterpoised the sources of life, and thus the circle of Providence is found complete—that which is rejected by each being acceptable to the other, and a perpetual interchange of supply and demand kept up. It is one of the most beautiful instances of the wisdom and beneficence of God to be found throughout His works of creation and providence. For the carbonic acid gas we animals give off is very poisonous, and if not removed from the air by vegetables, would very soon destroy all the higher animals. Boussingault applied manure containing a large amount of carbon, and still found that at least two-thirds of the carbon present in the crops must have been derived from the atmosphere; for without computing the unexhausted value of the manure after the removal of the crop from the soil, he found that

3,556 lbs. carbon in the manure yielded 8,196 lbs. carbon in the crops; and that 4,640 lbs. must therefore have been derived from the air in a five-shift course of cropping—potatoes with manure, then wheat, clover, wheat, and oats.

3,556 lbs. carbon in the manure yielded 8,010 lbs. carbon in the crops; and that 4,454, &c., with beet instead of potatoes.

4,267 lbs. carbon in the manure yielded 10,705 lbs. carbon in the crops; and that 6,438, &c., six years, potatoes, wheat, clover, wheat, followed by a winter (half) crop of turnips, peas with manure, rye.

1,450 lbs. carbon in the manure yielded 3,909 lbs. carbon in the crops; and that 2,459, &c., three-years naked fallow with manure, wheat, wheat.

Ammonia given off during the putrefaction of animal and vegetable matters containing nitrogen, escapes into the atmosphere, there combines with carbonic acid, and being washed down during rain, as carbonate of ammonia forms the chief source whence plants derive nitrogen—the soil retaining and acting as a liberator. By the application of nitrate of soda,—gluten and albumen, the valuable nitrogenised constituents of food plants—have been increased 24½ per cent.

§ 37. But the elements of which plants are composed unite to form, as we have said, either non-nitrogenised or nitrogenised organic portions of these bodies. Those which have no nitrogen are

	Lignine.	Starch.	Gum.	Sugar.
Composed of Carbon	50.00	44.44	42.10	36.36
„ Hydrogen	5.55	6.17	6.43	7.07
„ Oxygen	44.45	49.39	51.47	56.57
	100.00	100.00	100.00	100.00

Remark the great similarity in their composition.

§ 38. The lignine is to the stems and other parts of plants what the bones are to the animal frame, and varies greatly in different crops, and different parts of the same crop. Barley contains of it 4.8 per cent., its husk, 18.7; oat-bran, 34.0; husk of rye, 24.2; peas, 21.8; potatoes, 4.3 to 10.5.

§ 39. The soluble grains of starch found abundantly in all articles of vegetable diet, are enclosed, like the butter when still floating in the milk, in a membranous envelope, which bursts when heated with boiling water 212° F. and the solution gelatinises on cooling. Wheat flour contains 39 to 77 per cent.; rye flour 50 to 61; barley flour 67 to 70; oatmeal 70 to 80; rice flour 84 to 85; maize or Indian corn meal or flour 77 to 80; peas and bean meal 42 to 43; and potatoes 13 to 15 per cent. of starch.

§ 40. Gum besides existing in small natural quantities in many of our fruit trees, exists also in the seeds of flax and rape—and amongst the old-world remedies of the days when "lint was in the bell" now forgotten, the mucilaginous decoction of linseed was employed as a sovereign cure for coughs, colds, and incipient consumption. This is but one amongst many advantages lost through prejudice against the lucrative flax crop. Barleymeal contains 4.6 per cent. of gum; oatmeal 2.5 per cent.; wheat flour 2.8 to 5.8; wheat bread 18.0; Indian corn 2.3; rice, 0.1 to 0.7; peas, 6.4; the garden bean 4.6; potatoes 3.3 to 4.1, and marshmallow root the enormous per centage of 35.6. Observe the increase of gum in the manufacture of wheat flour into bread. It rises from 5.8 to 18 per cent., because a portion of the starch is during the process of baking, chemically converted into gum.

§ 41. Sugar exists abundantly in some of the substances known as food—in barleymeal there is 0.5 per cent.; in oatmeal, 0.8; wheat flour, 0.4 to 0.8; rice, 0.3; peas, 2.0; figs, 62.0, and beet, 6.0.

§ 42. The principal nitrogenised, or as they are sometimes termed azotised proximate principles of plants, are—

	Gluten.	Fibrine.	Vegetable Albumen.	Legumine.
Carbon	55.22	54.60	55.01	54.14
Hydrogen	7.42	7.30	7.23	7.16
Nitrogen	15.98	15.81	15.92	15.67
Oxygen with traces of sulphur & phosphorus	21.38	22.29	21.84	23.03
	100.00	100.00	100.00	100.00

§ 43. It is a favourite experiment to prepare gluten from wheat flour by washing it over a tumbler covered with muslin, so as to separate the starch, gum and sugar, which are precipitated amongst the water at the bottom of the tumbler, in the form of a fine powder, whilst the glary, adhesive gluten remains, afterwards identified with the fibrin of flesh by subjecting a piece of meat to

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* Mülder has lately disproved this identity.

the same process of washing. It is present in all grain crops; but perhaps, there is no constituent of them that varies so much in quantity, even in the same kind of grain, a difference of manure being productive of an equivalent difference of gluten. Wheat contains from 8 to 24 per cent.; rye, from 9 to 13; barley, from 3 to 6, and oats from 2 to 5.

§ 44. Vegetable fibrine found chiefly in the seeds of what we term the cereal grains, barley, oats, rye, wheat, is the essential part of the gluten.

§ 45. Vegetable albumen existing abundantly in the animal kingdom, where it is purely represented by the white of the egg, exists only in small proportion in the seeds of our food plants.

§ 46. And legumine, or vegetable caseine existing especially in the seeds of peas, beans, and the oil plants, constitutes 15 to 20 per cent. of the former. Its composition is the same as that of cheese, and indeed that of the azotised vegetable products resembles nearly blood and muscular animal fibre in composition.

§ 47. Such are the organic constituents of plants, with which chemistry has so minutely familiarised us, that Fromberg has decided the comparative values of certain items of food, according to their amount of azotised principles, and of starch, gum, and sugar. Taking beans as 100; peas are equal to 80; oats to 75; wheat, 70; maize, 60; rye, 55; barley, 50; potatoes, 45; rice, 35.

§ 48. The general inorganic constituents existing in the ash of plants are silica, sulphur, phosphorus, chlorine, potash, soda, lime, magnesia, alumina, oxides of iron, manganese, and fluorine.

§ 49. Silica is one of the most abundant substances in nature, and forms a large portion of the mineral crust of the earth. It is its abundance in the stems of plants, such as wheat, oats, and hay, that gives firmness to their structure and enables them to sustain the weight of their matured produce.

§ 50. Sulphur is found in some of the organic constituents of plants as fibrine and albumen, and in the ashes of all plants in the form of sulphates, many of which compounds exist in the soil, but the plant derives its supplies from the soluble salts, sulphate of ammonia, sulphate of lime, and sulphate of magnesia. Sulphuric acid or vitriol (16 S. and 24 O.) though highly corrosive in itself, when abundantly diluted with water, has been found to insure large crops of clover and other plants rich in sulphates.

§ 51. Phosphorus, which occurs in some even of the organic constituents (as albumen) exists as phosphoric acid (31 parts of which is phos. and 40 ox.) in great quantity in the seeds of wheat, barley, oats, peas and beans. The acid combines with different bases to constitute phosphate of lime, phosphate of magnesia, &c., which enter largely into the composition of bones. Hence has arisen the value of bones returned to the earth as a manure.

§ 52. The extent to which chlorine exists in the ashes of inland plants is small. One of its compounds, chloride of sodium, is best known as common salt.

§ 53. But potash, one of the three substances termed alkalis (the other two being soda and ammonia—lime and magnesia being alkaline earths) exists most abundantly in the ashes of plants, but always in combination with acids as carbonate, sulphate, phosphate, or chloride of potassium. Carbonate of potash being very soluble in water, is a powerful fertilizer, of the benefits of which we have an illustration in the effects of manuring with wood ashes; to which, however, the sulphate of potash also present in wood ashes partly contributes. The phosphate of potash is an important constituent of plants and a test of their nutritive value. The chloride exists but to a small extent.

§ 54. Soda, when existing abundantly in the soil, enters into the composition of plants instead of potash—especially in situations near, or it is alleged within seven miles range of the sea, which are liberally supplied, especially in storms, with volatilised particles of common salt—chloride of sodium—subsequently deposited on the surface of the land. Carbonate of soda occurs chiefly in the ashes of marine plants, sulphate of soda in the ashes of red clover, vetches, peas, and nearly all plants, producing in consequence beneficial results as a manure. Phosphate of soda, whose function of decarbonating the blood of animals Liebig has recently proved to render it indispensible in all articles of ordinary food, vegetable or animal, exists more or less in the ash of all plants. Common salt, the chloride, exists in all soils and ashes of vegetables—hence its efficacy used sparingly as a manure (for chlorine *per se* is very injurious to vegetation) and the success with which it is applied to the culture of cabbage, asparagus, seakale, plants originating on the sea shore.

§ 55. No commonly cultivated vegetable has been found entirely devoid of lime. It is present in most plants in large proportion, as well as in all soils. Existing in excess it is noxious to vegetation, but this circumstance is frequently made available for the destruction of noxious weeds and insects. From the rapid decomposition which it causes of organic matter in soils, its application to mosses, heaths, and unreclaimed lands, having a superabundance of vegetable matter is highly important—as this alkaline earth even neutralises the acids produced during organic decomposition, and prevents their exercising a poisonous influence on the crop. Gypsum, the sulphate of lime, is well-known as an agent for preventing the escape of ammonia, by causing it to combine with the sulphuric acid of the gypsum into sulphate of ammonia. Sprinkled over stables, compost heaps, fields lately treated with farm-yard dung, &c., it fixes the volatile ammoniacal salts, and retains these valuable matters in the soil for economical use. Phosphate of lime, the principal constituent of bones, gives them their great value as a manure; but requires to be dissolved in acids to become available to plants, being insoluble in water: hence sulphated bones, that is bones dissolved in sulphuric acid, diluted 150 times or so with water, form certainly one of our best manures for wheat, oats, or any plants whose seeds are rich in phosphates. 8lbs. of bones supplying the phosphates for 1,000lbs. of straw, and 20lbs. of bones for 1,000lbs of wheat or oat grain.

§ 56. Magnesia we find as a phosphate in the seeds of wheat and oats; but I dare say most of you will be best acquainted with its sulphate—vulgarly called Epsom salts.

§ 57. Alumina scarcely exists in plants, and does not contribute directly to their nutrition; of the oxides of iron we have already made mention—the other inorganic constituents are inconsiderable.

§ 58. Chemistry thus determines the inorganic constituents of plants, and although these must vary slightly according to the soil or the season, its analysis provides the agricultural instructor with a correct notion of the proportions in which these constituents must be contained in the soil in order to produce any particular crop. Nay, it was held by Professor Johnston—taking straw to be equal to twice the weight of grain—that if the produce of a field be at a given rate, say 25 bushels of wheat, each 60lbs. weight, we can tell the exact amount of constituents removed from the soil, both in the 1,500lbs. of grain and the 3,000lbs. of straw, and the amount required to be restored for these abstracted ingredients so as to keep the soil in a fertile condition.

§ 59. This circumstance is the chief characteristic of the theory of manuring under the *regime* of scientific agriculture. But the doctrine and details of the application of manures occupies a far more important section of the science of agricultural chemistry than this, although the doctrine of restoring the substances abstracted by vegetation be its leading feature. These details, which become the more extensive from taking into consideration not only those manures which act directly on the plant and enter into its constitution, but also those which merely prepare its food by the decomposition of matters remaining insoluble in the soil. Here also comes in the theory of rotations. Crops of different plants, as established by Boussingault, abstract during their growth quite different quantities of inorganic matter from the soil. Thus, in a five years rotation, the 1st year potatoes, 246.8lbs. were abstracted; the 2nd, wheat, 371; the 3rd, clover, 620; the 4th, wheat with fallow turnips, 488.8 and 108.8 respectively; and the 5th, oats, 215lbs. of ash.

§ 60. Liebig found that besides containing different weights of ash or inorganic matter, crops differed in regard to the constituents of their ash; and hence he proposed a classification, from which he anticipated in the hands of the practical man a much improved alternation or rotation of his crops. He distributed agricultural plants into three classes, Silica, Lime, and Potash plants, according to the predominance of these items in their ash—wheat, barley, oats, and rye coming under the first; peas and clover under the second; and turnips, potatoes, beet-root, and the Jerusalem artichoke under the third denomination. He begins his rotation with the potash plant (say turnips), because immediately after manuring with farm-yard dung such plants would absorb the soluble active alkaline matters, and prevent their being dissipated by rains, and because these matters being less required by other crops would otherwise have to remain in the soil. Potash plants, moreover, would suffer portions of silicic acid, which these other crops do require to be separated and rendered soluble for the silica plants, against their turn, which is next in the rotation (say wheat). Neither the potash nor the silica plant demanding much lime, the lime plant (say clover) beautifully succeeds in the third place of the rotation. During its growth the land, in a great measure, obtains rest after the exhausting action of the silica crop; besides, although the silica plant requires phosphates in addition to silicic acid, it will be found that the lime plant will, in succession to it, benefit also by that important ingredient, and leave just sufficient in the soil to mature the seeds of a fourth crop of oats or rye. This four shift rotation is founded on the purest scientific principles. But, perhaps, the quantity of phosphates, alkalis, lime, or magnesia existing in the soil may fit it to yield more crops in a rotation. Its supply of inorganic constituents may be, and frequently is, found sufficient for two successive potash or lime plant crops. Thus in the four shift, turnip might be followed by wheat, then by clover, and lastly by peas. Nay the inorganic supplies in the soil might suffice for two or three silica crops in the rotation—turnip, wheat, clover, oats, and peas. But the authoritative maxim of rotations is this, "the greater the variety of crops grown, the longer the interval between successive crops of the same kind, the more perfectly does the agriculturist obey the principle of rotation, and avail himself of its benefits." Having run through the series of alternations thus dictated by the conditions of the soil, the agriculturist must, of course, begin anew by restoring to the soil not only all the inorganic but all the organic values abstracted from and not contained in it. All this chemistry teaches him to effect; and I think we have thus a glimpse of its importance as a branch of agricultural education.

§ 61. Perhaps it may be said that chemistry, confining its inquiries to analysis, can never throw any light philosophically upon those recombinations of matter which constitute the phenomena of vegetation. Yet even towards this consummation I suspect we are approaching through the new German doctrines of Eremacausis and Catalysis. The German chemists seek to explain that growth or increase of products and the multiplication of quantity, the law of which has been hitherto undetected, by ascribing it to something like what takes place when a little yeast or leaven introduced into a mass of unfermented paste or dough, diffuses its influence through the mass to its own destruction certainly, but greatly to the increase, in kind, of the principle of which it consisted. Thus, also, chemists ascribe the conversion of the starch of plants into sugar to the existence of a vegetable principle called *diastase*, an extract obtained from malted barley, from oats, or from wheat. It is a solid white substance containing nitrogen, which is soluble in water but not in alcohol. One part of diastase is sufficient to convert, in a few hours, 2000 times its quantity of starch into sugar, (not cane sugar, recollect—but grape sugar, much less sweet, and much less soluble). In proportion as the diastase acts on sugar, it disappears itself. Germination, like reproduction, emanates from actual decay. The seed or set committed to the ground, dying, gives birth to a new progeny of plants at the expense of its own existence. Liebig has stated, also, that when the oxygen of the air acts upon dead vegetable matter, this slow combustion or eremacausis converts the carbon and hydrogen present into carbonic acid and water. But the increase in constituent quantity perceived in the case of nitrogen, is, perhaps, the most striking; for Mr. Hyett, by the application of nitrate of soda as a manure, obtained an increase of 24½ per cent. of nitrogenised constituents, as already mentioned, over what had been obtained without the application of nitrate. Now whence was this addition of nearly one-fourth the bulk of these constituents in the crop, so far exceeding the quantity of nitrate that had been applied; and whence even the ordinary bulk derived independent of the application? if not effected by some chemical conversion? The laugh which has been so frequently raised by the retort when Lord Kaimes' announced that one day it might be possible to carry in the waistcoat pocket as much manure as would serve an acre—and his gardener replied that then it would also be possible to carry off the produce in the same sack—may yet be silenced when we have discovered the true principle on which the diastase propagates two thousand times its bulk in sugar, or that on which slow combustion, which effects the chemical changes in the soil, causes it to yield year by year such quantities of nitrogen that it is at present impossible to conceive whence it can proceed.

III.—VEGETABLE PHYSIOLOGY.

§ 62. Vegetable physiology examines the structure of plants, the form, arrangement, contents, development and functions of their cellular and vascular tissues: the structure, arrangements, special functions of their organs of nutrition and vegetation, whether the general integument, the stem, the root, or the leaves. It takes a general view of the food of plants, whether in reference to their chemical composition, to that of the soil, or the application of manure; but treats, as its more especial province, the action of light upon plants, their absorption, circulation, respiration, products, secretions, and reproduction. It is but too true that this science, lying so directly in the way of the agriculturist, has been less attended to than its obvious importance demands. Not only is vegetable, but animal physiology of importance to the agriculturist; and all sound agricultural education must henceforth embrace and embody the laws and results of both these great sciences, so far as they bear on what a recent author on the subject—the late Dr. Lindley Kemp—calls "the art of the manufacture of animal and vegetable food." It is in vain to expect that chemistry, which has hitherto been taught as the sum of agricultural science, will supply the want of knowledge arising from the omission of these. Chemistry, as we have already seen, is, in reality, the alphabet of all the physical sciences; and writers on agricultural chemistry have always found it incumbent to mix up with their texts some explanations of physiology, as physiologists have inevitably to introduce those of chemical principles. But chemistry deals not with the vital world, with which the agriculturist becomes engaged. The laws and forms of chemical affinity and inorganic combination, are quite distinct from those of vital affinity and organic action.

IV.—BOTANY.

§ 63. Botany is a science for which, amongst agriculturists, a distaste has, in a great measure, arisen from the formidable lists employed in its Taxonomy to give names and classifications to the innumerable host of vegetable productions of the globe. This, however, Professor Balfour repudiates as a most erroneous view of the science, though fostered by the advocates of the Linnæan system. Our botanists, you are perhaps aware, adopted the natural system proposed by John Ray, and carried out by the great French botanist, Jussieu. Studied upon these philosophical principles, botany now takes an enlarged and comprehensive view of the vegetation with which the earth is clothed. In its relations to agriculture, "the consideration of the phenomena connected with germination and the nutrition of plants, has led to important conclusions as to sowing, draining, ploughing, the rotation of crops, and the use of manures." From no other science could we secure satisfactory information regarding the comparative qualities and productiveness of plants, or the advantage and practicability of extending agriculture by the introduction of new species and desirable varieties.

V.—ANIMAL PHYSIOLOGY AND ZOOLOGY.

§ 64. Animal physiology and zoology take the same positions in the curriculum of agricultural study in reference to the animal, as vegetable physiology and botany do in the vegetable economy. To the one we are indebted for a knowledge of function, to the other of species. To the latter more especially are we indebted for those immense strides by which the breeds of our domestic cattle have been pushed to that perfection, first deemed possible by the Bakewells and the Cullings, within the memory of some yet living—but indebted for success entirely to science. But even as regards the functional study—how it is possible for persons to undertake the care and management of a structure so nicely and intricately arranged as that of any of the higher animals, densely ignorant of the real character and relations of the living machinery—we should be at a loss to conceive, were it not obvious that mismanagement, gross error, and absurd practices, either infest the management of stock, or some little acquaintance with the truth has been forced upon breeders and others by their experience. To study the food and digestion of animals—their respiration—the nature of animal heat—reproduction and death, is, in fact, a more pressing matter of necessity from the consequences that ensue from ignorance, than to study the functions and state of plants, where the responsibility is less, and the danger by no means so imminent.

VI.—METEOROLOGY.

§ 65. Ere passing from the natural sciences there is one, too much talked of, yet too little studied—Meteorology—which more concerns, as it certainly more interests, the cultivator than almost any other; which the ancients studied with a degree of intelligence truly astonishing, although they called in the aid of their not altogether empirical astronomy and even astrology to assist them; but which we, for the most part, treat with vacant wonder, and make the theme of idle gossip.

§ 66. The atmosphere and its currents—in other words, the weather—indeed, presents before us a boundless field of investigation, but not altogether without its landmarks. The nature and constitution of our atmosphere—its height and weight—the application and use of the barometer—atmospheric temperature and density—the phenomena of its movements—the velocity, force, and local prevalence of winds—the nature, causes, and course of storms, with their correct instrumental indications—vaguely as we talk of them, and much as our country people would give to master their intentions, have all been made the subject of careful study and observation. Colonel Reid has laid down the law of storms in all its importance to navigation; but Professor Daniell has also determined that in Great Britain the 10 years average of westerly winds to easterly is as 225 to 140, and of northerly to southerly as 192 to 173; and facts of this class are of serious importance in agricultural operations. The visible vapours of fog and cloud filtering through the interstices of our atmospheric gases as through a sponge, also seriously affect the interests of the agriculturist, who has to regard them not only after accumulation but in their evaporation, so as to estimate their effects; and he may find it something new to be told, as we are by one observer, Lesslie, that even ploughed land will supply as much moisture to the exhaling fluid as an equal sheet of water; and he may be able to judge more clearly of the effects of rain when he hears that a cubic mass of air, measuring 20 yards each way, of a temperature 68 deg. Fah., requires 250 lbs. troy of water to bring it to the point of saturation. The measure of moisture is effected by the hygrometer; and by that little instrument, through dint of calculation, it is found that in this little island an annual superincumbent weight of 141,832,558,752 tons of water rises by evaporation from the face of the country over our heads. But, thanks be to science, the distribution of all this mass of rain throughout Great Britain is known. Why, we know the very clouds by name—Cirrus, Cumulus, Stratus, Cirro-cumulus, and Cirro-stratus—down to Nimbus, the rain-cloud, according to Mr. Luke Howard's ingenious nomenclature. Then the annual amount of the fall of rain—the monthly quotas—crystallization into snow, hail, and ice—the striking facts connected with the deposition of dew, which is occasioned by the temperature of substances being reduced below that of the atmosphere—all these things, embraced in the study of meteorology, rank high in importance in out-door operations. But physical climate—or the science of climatology, for it ranks as a distinct science—is the philosophy of the minute facts marshalled under meteorological observation. The study of the varieties and sub-varieties of climate, so varied by altitude and modified by circumstance, becomes intensely interesting to the agriculturist in his locating, his operating, and improving.

VII.—HY[illegible]STATICS.

§ 67. In no one thing have the effects of scientific education upon agriculture been more peculiarly marked than in draining—that great improvement by which the soil and surface of the country has been rendered mechanically more susceptible of manipulation, and chemically more productive. A want of knowledge of the most ordinary principles of hydrostatics completely restrained the progress of this improvement till the days of Smith of Deanston. The miner, the well-sinker, the plumber, every mechanic and labourer, save the farmer and the drainer, was aware that the perpendicular weight and pressure of water is infinitely more intense than its trifling lateral pressure. But the agriculturist could not bring himself to recognise the truth; and the extraordinary preference accorded to shallow over deep draining at the present day, makes it doubtful whether he has been brought to comprehend it yet. These defects, education has yet to remedy by an explanation of hydrostatic principles as a branch of practical education.

VIII.—PNEUMATICS.

§ 68. This science, which details the properties of air, in like manner contributes its quota of information to agriculture on all matters connected with the circulation of air, now not less important as an element in general drainage than in above-ground ventilation.

§ 69. For example, how few farmers will we find who understand the cause of comparatively dry soil resisting water, as exhibited, on a small scale, when we attempt to saturate the earth in a flower-pot, and find that the water will not enter, but appears to rest upon a plate of silver, being nothing but a coating of air which the earth has retained by its adhesive power, and which must of necessity get out, in order that the water may get in, and therefore an ominous pause ensues.

§ 70. In like manner, how few even of the best informed exactly comprehend the action, or, as they phrase it, the *drawing* of a drain, through its derangement of the neighbouring hydrostatic arrangements, causing unequal heights of the water suspended by capillary attraction in the soil from the descent of a portion into the drain, which, leaving part of the surface dry, the adjacent portions are forced to give up part of their moisture in the direction of the drain, claiming in their turn a similar tribute from portions more distant, while the drain continues to empty off the supplies as fast as they are received. Until these simple truths are systematically taught amongst our rural population, agricultural improvement can make but little real progress, and must always run the risk of being deprived of half its value. Uneducated in principles of this nature, practical experience will do nothing but bewilder the farmer.

IX.—PRACTICAL MECHANICS AND ENGINEERING.

§ 71. Practical mechanics and engineering, finally, contribute additional aid from the inventive sciences to promote the objects of agriculture; and their cultivation, which is eminently practical work, is obviously important to the cultivator of the soil. If ignorant whether he is applying a mechanical power acting as a lever, a wedge, a pulley or a screw, and still less acquainted with the probable value of these powers and their modifications—how can a man be expected to be able to produce or select an available agricultural implement, adjust its draught point, or proportion his propelling power to the required amount of traction?

§ 72. The structure of the plough has certainly reached a pitch of nicety in the hands of our intelligent and enterprising implement makers, which leaves the modern farmer of civilised districts very little to do but select, if he chance to possess the knowledge. But the pulverizers, and, with exception perhaps of the two horse cart, even the draught vehicles of agriculture, frequently altogether inefficient, occasion for the most part a great and unscientific waste of power.

§ 73. To forward that great triumph of ingenuity over toil, which nowhere has proved more remarkable than in the introduction of the larger machinery of the farm, must necessarily be considered important to the agriculturist's profits; and beyond this the adaptation of the steam or water power employed upon the farm to act upon *all* the branches of labour on the steading, may contribute still more essentially to enable him to distance competitors in the race of gain. Nor is it less important that a full knowledge of the mechanical principles and construction of implements, and some acquaintance with those of other machinery, should be imparted to the humbler assistants of the farm.

SOME ACCOUNT OF THE SCHOOLS OF AGRICULTURE.

There still remains, as a subject for tuition, Practical Agriculture proper, of which many pretend to see no way of imparting a knowledge save by an ordinary apprenticeship on the farm; and I am ready to concede that this is a matter wherein example goes before precept. I should have been still more ready, however, to have granted this, had we no examples of educational establishments primarily devoted to agriculture, attended with much success, and fairly warranting the inference that this essential branch of industrial instruction may be universally applied in country schools, as an improvement in the direction of practical education upon their ordinary elementary course. I am aware that the objection will meet me *in limine* that the attendance of scholars, especially of the poorer classes, is now so stinted at school that time is scarcely afforded for imparting elementary instruction alone. But it occurs to me that, combined with practical classes or supplemented by practical objects calculated to advance their views in life and to forward their objects even in gaining employment, *that* attention would be recalled to the school, and *that* attendance bestowed upon it which the stern pressure of necessity now compels many a pupil to relinquish in order to begin "life in earnest." This is taking low ground. The grand advantages to flow from practical instruction in agriculture being imparted on any terms, from habits of industry and a knowledge of operations being formed, and an effective industrial system being thereby established, are beyond all price, and ought to require no plea and no incitement.

It is, unfortunately, too true that the knowledge I propose should be imparted meets with least favour from the class to which it is specially addressed, and that other objections exist, or have been urged, against making agriculture part of the educational system. These last are—that the teacher becomes apt to follow out the study of Chemistry as an amusement, losing sight of Agriculture—a narrow-minded objection truly, if, in one case in ten, it were even likely to be true, of the zealous and conscientious body to which it has been applied! but which is totally removed in the view I take of agricultural instruction—wherein chemistry should only hold its place, and no more, as in any other of the mixed sciences; and, as experiments to prove chemical facts are not wanted, so the expense of apparatus would be saved.

The first model for an agricultural school was that of De Fellenberg, at Hofwyl, in Switzerland. It was both a school and a farm on the self-supporting principle, or rather on two principles: one establishment, self-supporting, to which De Fellenberg devoted his large fortune, being for poor boys; whilst the sons of the better classes were received as boarders at another, under the same management. The Prussian State School of Agriculture, at Mogelin, had, under the famous agricultural writer Von Thaer, in 1820, a college and model farm of 1,200 acres; a professor of mathematics, chemistry and geology; another of the veterinary art; and a third of botany, materia medica, and entomology, who all lived upon the spot; whilst a practical agriculturist communicated the mode of applying the sciences in husbandry. Many similar institutions, erected under royal patronage, have appeared in Prussia, and throughout Germany—even in Russia, in Holland, and in France—such as that at Hohenheim, near Stuttgard, in Wurtemberg, where an old palace has been converted into a college for the reception of agricultural students, and possesses, within a ring fence, a farm of 1,000 acres. Two classes attend this seminary. To one class the fees charged are equal to £37 sterling, and with extras amount to £50; but the natives of Wurtemberg are admitted at a lower rate. Here the students merely inspect and superintend the operations of husbandry. Twelve professors lecture to them on mathematics, physics, chemistry, botany, tillage, rural economy, forestry (always a great leading object in the rural schools of Germany, and gaining importance in our own country), and veterinary science. There are agricultural training schools at Eldna, near the University of Griefswold, and also near Frankfort-on-the-Oder, similar to the school of Hohenheim. The Emperor of Russia, twelve years ago, established a school on the north bank of the Neva, not far from St. Petersburg, where his serfs are sent for five years to be educated in practical farming and the use of the most approved modern implements. Sixty of these serfs are sent out every year to carry the skill and knowledge thus acquired by them throughout the different provinces of the empire. There is, besides, an agricultural college at Moscow. Even in France, a model establishment—Grignon—formerly one of the royal demesnes, with a farm of 1,100 acres, was founded in 1827, on a capital of 600,000 francs, raised in 1,200 franc shares. The pupils, of two classes, actually aid in working the farm, receiving diplomas on passing a public examination. At Rennes, in Brittany; at Limours, near Rambouillet; and at Grandjouan, near Nantes, there are schools of agriculture: that at Limours is a normal school; and that at Grandjouan, for training the youth of the labouring poor, is described as an institute of agriculture, model farm, agricultural implement factory, and agricultural colony for the reclamation of 500 hectares (equal to 1,200 acres) of land. The Dutch Agricultural School, at Groningen, has attached to it a farm at Floren—but the half-yearly commencements divide the year into a summer and winter period: the agricultural course of winter study being without charge to the pupils in town, who board themselves and pay about £4 for the extra branches of science, including natural history, chemistry, botany, natural philosophy, mathematics, and the united application of chemistry and mechanics. The cost of the whole year's instruction, including, if requisite, French and German, is £33 sterling. In Ireland, where, strange to say, we have the best examples of schools purely agricultural, after the Hofwyl model, an establishment started at Bannow, in the county of Wexford, flourished for about seven years subsequent to 1821. The apprentice system of Germany not being followed so as to attach the students to the school for a term of years, it ultimately was given up. In 1826 arose the Templemoyle school near Londonderry, an establishment which cost originally £4,000, contributed by £25 shareholders having the power of nominating pupils. There is accommodation for 70 pupils, and a farm of 172 acres. The pupils, who pay an annual board of £10, are received between the ages of 14 and 17, and are expected to remain two or three years. Separated into two divisions, they go through the routine of in-door study and outdoor labour in alternate sections, being taught in the school the various branches of a useful education, including geometry and land surveying, and on the farm practical husbandry. Professor Johnston attended their examination at Templemoyle, in 1845; and from his address on that occasion I learn that the examination did credit alike to the pupils and their instructor—being one which not one in a hundred could have conducted. The institution, however, was then under a debt of £200. Their farm, when inspected, was free of weeds. They had opened a little library, and the statistics of the institution showed that from 33 boys in 1835, and its complement of 70 in 1843, the institution had risen to have 90 in 1845; 499 boys having then been educated at the institution from its commencement—93 of whom, remarked as the most enterprising and intelligent, had emigrated. The Larne boys, some of whom were brought over to Edinburgh as a deputation intended to inspire the parish schools with encouragement to introduce agriculture, as well as show that it does not interfere detrimentally with the other branches taught, were also examined for that purpose on a previous occasion at Glasgow, in 1844, in the ordinary branches of education, when a recommendation was issued for imitating their examples, upon which recommendation 100 of the parochial schools of Scotland were shortly reported to have acted. I would hesitate to say that anything like a hundred have persevered in that course. The want I have adverted to consists in the want of normal instruction, to which I earnestly urge attention, not one institution for affording which do we, at this moment, possess in England; for I find it stated, in Mr. Mechi's balance sheet, that the Royal Agricultural College of Cirencester, with its staff of professors of the highest eminence, is considered to require a preparatory school to enable it to go on. In England our preparatory schools must be the ordinary national schools. The Royal Agricultural College of Cirencester, incorporated by Royal Charter in 1845, is founded upon a capital of £24,000 in £30 shares, conferring a right of nominating pupils, who must be under 20 years of age; although out-students are also admitted to attend the lectures and practical instruction. The charges are, for in-students £80, and for out-students £40 per annum. The farm is 450 acres in extent, 420 of which are arable. To this I may add the private College at Maidstone, in Kent; and the eminent school of Mr. J. C. Nesbitt, in London. Besides the now celebrated Albert Model Farm, at Glassnevin, near Dublin, which has risen to eminence on the Templemoyle model—the Queen's Colleges in Ireland have now also chairs of agriculture attached. But the most advanced views of agricultural education I have seen anywhere proposed are those put forth in America, under the auspices of Professor Norton, on behalf of the New York State Agricultural Society; and Canada has recently copied the example in her chair of agriculture and model farm at Toronto. The State of New York proposed to endow an agricultural school and model farm. The school to embrace one department for mechanics, mathematics, and the physical and practical sciences; another agriculture proper, treating of soils, crops, rotations, fertilising, irrigation, draining, preparation of the ground, putting in, cultivating, harvesting and securing crops; and in connection with this department agricultural chemistry as well as vegetable physiology would be taught. The veterinary department is intended to include the management of dairies, and even botany in reference to the grasses and food useful for animals. The ground of this recommendation was that in America they wanted an institution to teach *American* and not English or German farming; for although the Germans were said to be most conversant with the theory of agriculture, German agriculture would not answer in America; neither would English, since twice as much per pound being obtained for a bullock as the meat would sell for there, the same treatment would not be justifiable in point of mere expense. The same reasoning applies to ourselves. If we have agricultural instruction it must be national; and we ought, at least, to possess one national institution capable of providing instruction for all the country by qualifying those who are to teach the ordinary branches of education; for I think my remarks must have tended to establish that such can be done, as well as to expiscate the character of the work required to be undertaken. America learnt the necessity of agricultural instruction in the hard school of experience; for Maryland, Virginia, North Carolina, and the older states, exhausted by reckless, ignorant, and protracted forcing of wheat and tobacco crops, will no longer produce them, and are abandoned to waste. We trust no such lesson may be ours.

I will now, therefore, express a hope that the oft recorded blessing on the man who shall make two blades of grass to grow where only one grew before, may be found to descend on many whom I now address. Bear in mind the words of Liebig, "Cultivation is the economy of force. Science teaches us the simplest means of obtaining the *greatest* effect with the *smallest* expenditure, and with *given* means to produce a *maximum* of effect. The unprofitable exertion of power (physical or pecuniary), the waste of force in agriculture, or in other branches of science, is characteristic of the want of knowledge." And can the enlightened people of this great country want knowledge? Ask at the workhouse, the prison, the police office, the back-streets and courts, the village hovel, and the beggars lodging house; enquire on the bleak uncultured waste abandoned to the coney or the grouse, in the miserable shielings, the abodes of rural destitution; at the wan and wasted emigrant, dragging with him his last drain of value away from his sphere of social depression; at all the unimproved lands and mismanaged farms; at all the symptoms of what is called agricultural distress—ask, and all the many voices of population and punishment, vice, misery, destitution, disease, and despair, will concur in saying that it is solely and exclusively within the power of the instructors of the people to ameliorate, if not to remove, with the Divine permission, our social afflictions.

QUESTIONS.

1. How has agricultural instruction hitherto been regarded?

2. Of what does the intelligence of the cultivator stand most in need?

3. What is the general state of population, its relative numbers in the world, and in Britain by the last census?

4. What are the resources of the earth, as illustrated by the state of cultivation in China and in the United Kingdom?

5. How may pauperism, destitution, and crime be overcome?

6. What then has British agriculture to accomplish?

7. State the extent of cultivated, improvable, and unprofitable areas in England, Wales, Scotland, Ireland, and the Islands respectively?

8. How stands the distribution of British cultivation, as respects arable and garden lands contrasted with meadows, pastures, and marshes?

9. Quote the most recent statistics of the distribution of cultivated and waste lands in the United Kingdom?

10. How many acres is it supposed we could cultivate to the full extent, and what amount of population would they sustain? Mention an instance illustrative of accessions of human food by the progress of improvement in agricultural operations?

11. Whence is agriculture destined, however, to derive most aid?

12. What place do the sciences hold in relation to agriculture? And what popular writers concur in stating that their intimate study is unnecessary for the farmer?

13. What other circumstance restricts the farmer to the mere acceptance of their ascertained truths?

14. For what is the aid of geology requisite in agriculture?

15. How is it allied with chemistry in that science?

16. What are the general ingredients of soils?

17. In what do fertile and barren soils chiefly differ, according to Sprengel?

18. What is the action of silica?

19. What is the nature of common clay?

20. What are the effects of peroxide and protoxide of iron in soils?

21. What is lime and its agricultural importance?

22. How do rocks become disintegrated?

23. Of what value is potash in a soil?

24. How are changes effected on the earth's crust?

25. What are the agencies by which they are effected?

26. What is the action of air?

27. What that of water?

28. How does vegetable disintegration proceed?

29. What is the place of chemistry in agriculture?

30. How are the constituents of plants, animals and soils distinguished?

31. Name the four gaseous organic elements, &c.?

32. Describe oxygen?

33. ——— hydrogen?

34. ——— carbon?

35. ——— nitrogen?

36. What are the sources of these?

37. State the composition of non-nitrogenous bodies?

38. What is lignine?

39. How does starch exist in vegetable products?

40. In which of them does gum exist?

41. In which of them does sugar exist?

42. Name the azotised principles?

43. How is gluten shown to exist in the flour of grain crops?

44. Where is vegetable fibrine chiefly found?

45. Is vegetable albumen largely found in seeds?

46. What is legumine?

47. How do the above constituents decide the value of food?

48. Name twelve inorganic constituents of plants?

49. What is silica?

50. How and where is sulphur found in plants?

51. In what form does phosphorus occur?

52. Does chloride exist in the ash of plants?

53. What is potash, and how does it occur?

54. Is soda ever substitued in nature?

55. Is lime universal in cultivated vegetation? and what are its influence and effects?

56. Where does magnesia occur?

57. Does alumina exist in or contribute to the nutrition of plants?

58. What is the office of chemical analysis?

59. On what is the theory of manuring based?

60. Describe Liebig's chemical rotation of crops.

61. What is the German doctrine of catalysis?

62. What does vegetable physiology accomplish?

63. Of what use is botanical taxonomy?

64. What positions do animal physiology and zoology hold in the curriculum?

65. Is meteorology important to the cultivator, and how

66. Instance some of its disclosures?

67. What science relates to draining?

68. How does the science of pneumatics apply to agriculture?

69. What occasions resistance to moisture in dry soil?

70. What are the conditions on which a drain will draw?

71. What aid do mechanics and engineering contribute to agriculture?

72. What advancement has the structure of the plough and pulverizer reached?

73. How is farm machinery to be systematised?

74. Where are the chief schools of agriculture, and how are they constituted?

LECTURES ON AGRICULTURE.

DIVISION II.

OPERATIONS OF AGRICULTURE.

§ 1. Limits of Small Holdings, and Spade or *Petite Culture.* 2. Manipulation of the Soil. 3. Chinese repeated Ploughings. 4. Roman Furrow and *Scarificatio*, and Jethro Tull's Drill System. 5. Theory of Pulverization and Commingling of Ingredients. 6. Advanced Improvements, Draining and Deepening the Soil, and rendering it Friable. 7. Elkington's System. 8. Smith of Deanston's Thorough Drainage. 9. Old Advocates of Deep Drainage (Bligh and others). 10. Effects of Wet and Evaporation. 11. Hygrometric Balance. 12. Change in Mechanical Texture of the Soil by Drainage. 13. Experiments at Strathfieldsaye, by Mr. Parkes. 14. Professor Phillips on the Porosity of Clays. 15. Gray, of Dilston, on Deep and Shallow Drains. 16. Mr. T. Scott on ditto. 17. Mr. Hewitt Davis,—"To Drain or not to Drain?—that is the question." 18. Geology and Draining. 19. Number and position of Drains. 20. Stone Drains of Aberdeenshire. 21. Turf, Wood, and other Drains. 22. Laying Fields perfectly Level after Drainage. 23. Subsoiling. 24. The Subsoil Plough, and mode of working it. 25. Formation of Moorland-pan in unimproved lands. 26. Deterioration of Grass-lands from wet. 27. Importance of Deep Cultivation and the Admixture of Soils. 28. Bakewell's Testimony. 29. Smith's pecuniary results at Deanston. 30. The Polmaise System of Winter Fallowing. 31. Prejudices against Deep Ploughing. 32. Depth to which Plants strike their Roots. 33. The Art of Ploughing. 34. True form of the Furrow-slice. 35. The Swing *versus* the Wheel-plough—subsequent operations in a Six-shift Rotation: 1st, Oats—2nd, Potatoes and Mangel—3rd, Wheat—4th, Turnips along with Carrots—5th, Barley with Grass-seeds—6th, Grass.

§ 1. In our previous lecture were stated fully, I trust fairly, and I am sure sincerely, the claims of agriculture upon education. They are neither few nor small; and it is erroneous to suppose them limited to a class. As the most open remedy for the evils of a redundant population, this leading branch of industrial instruction demands, at least, universal adoption in our rural seminaries. We have twenty-seven millions and a-half of population to be provided with food, out of 77 million acres of land, 64 millions of which are susceptible of cultivation; and it is a very simple proposition to ask the means of enabling the people of this country to perform so plain and easy a task. I attempted to show the possibility, indeed, of maintaining many times the population of our islands on their arable surface. But I am not urging the poetical rather than possible proposal that every rood of ground should maintain its man. That would be to reduce to the agricultural labour-level every head of the population; and experience has told us, with fearful precision, that there is a limit beneath which it is unwise to reduce the agricultural holdings of this country. In the case of the Irish and Highland Crofters, for example, it is agreed on all hands, that sixteen acres form the least extent to which the Crofts should individually be restricted. Below that scale agriculture degenerates into a dead and indifferent occupation, insufficient for the subsistence of labour, or the encouragement of exertion and improvement. Sir John McNeill, the Scottish Poor Law Commissioner, in his report on the Western Highlands and Islands, mentions, even in reference to the system of spade husbandry, or *petite culture* practised in Belgium and elsewhere, which has been recommended as a means of enabling a whole rural population to maintain itself, *and to pay rents*—that the Crofting system of the Highlands, from its introduction early in the present century, has been precisely a system of *petite culture,* and has been carried on by spade husbandry. He does not, indeed, say that the cultivators were ever in a situation to try the requisite productive knowledge, in which Dr. Mackenzie's experiment at the Gairloch proved them to have been lamentably deficient, to bear on their operations. But he attributes the difference of results to the different climate and circumstances in which it is carried on, and the different character and habits of the people who practise it. Mr. Clark, of Ulva, a most intelligent gentleman, repaired to Belgium in 1846, on purpose to study the system of *petite culture,* in order that he might introduce it on his Highland estate. "The result of my investigation," he says, "was to convince me that the Belgian system was altogether unsuited for Ulva, or any part of the Hebrides, in consequence of the better soil and finer climate, the vicinity of markets, and the comparative smallness of the public burdens." Concurring with a reverend gentleman who has given peculiar attention to this peculiar topic (the Rev. Dr. Begg), that the Crofts ought never to be diminished below sixteen acres in extent—I still conceive that ignorance, and the consequent debasement of the people, have had infinitely more to do with the failure of the *petite culture* in the Highlands than soil, climate, markets, or public burdens; for the cases of Miss Martineau's cow-keeping, in Cumberland; of Mrs. Gilbart's schools, in Sussex; the *Low* Farming at Armagh Palace Farm, under Mr. Yule, the Archbishop's overseer; and the *High* Farming under Lord George Hill, at Gweedore—are all alike instances in which energy and intelligence alone, without any superior practical knowledge, have led to remarkably profitable results; the two last being cases in which both intelligence and practical experience combined to produce such a measure of success out of spade-husbandry and manual labour on a large farm, and out of small capital on a large estate, as to lead the authors to dream of removing not only

Irish, but (by force of example) Scotch and English distress also, by what the one calls low or cheap farming, in contradistinction to that system of high and expensive culture which is now the fashion in agriculture; and the other simply regards as the system of rural improvements pursued at Gweedore. We are not at present ripe for leading to a conclusion on the respective merits of high and low farming; although (in a course such as this) it may be essential to fix the minimum size of holdings, since it seems impossible to hold out the hope of subsistence on less than sixteen acres. On all hands it is conceded—even by Sir John McNeill, who, despairing of the Highland population being roused to profitable industry at home, recommends the wholesale calamity of emigration—that "education" is competent to aid and improve industrial results. Thus, he says, in concluding his report, "Instruction in agriculture and the management of stock would facilitate the production of the means of subsistence." A more secure tenure of the lands they occupy would tend to make industrious and respectable Crofters more diligent and successful cultivators. But the effects of all such measures depend on the general management with which they are conducted through a series of years; and it would be useless to dwell upon improvements which every one admits to be desirable, though few have succeeded in promoting them to any notable extent. It is curious, and perhaps mortifying to observe how little the difference of management and the efforts of individuals appear to have influenced the progress of the population, and how uniformly that progress corresponds to the amount of intercourse with the more advanced parts of the country, and the length of time during which it has been established.

§ 2. All this is sufficient to show us that it is not from individual efforts that anything is to be expected in the way of agricultural improvement thoroughly and minutely permeating the country; but, from a Normal system of instruction, such as I have long been humbly advocating, I would certainly anticipate superior results. When every one comes to be taught at school the doctrines, and to some extent, the practice of improved cultivation—a very different feeling will be engendered from that with which the gaping rustics of the existing generation stop and gaze upon the attempts of any isolated neighbour to deviate from the common track. Recollect, I neither hold out to cultivators the golden dreams of agricultural alchemy, nor proclaim that the ordinary produce of the farm is to be doubled, trebled, or quadrupled by adherence to certain scientific rules. The chief object of sound husbandry is to gain such an understanding of its nature as to prevent waste. That is the true economy of agriculture; and Liebig himself (in the sentence with which I concluded my last address) has proclaimed nothing else, whatever may have been done by the over-sanguine among his followers. My last was a scientific outline of what composes the theory of applied agriculture; the present lecture commences a more practical investigation, and is directed to expiscate

THE PREPARATION REQUIRED BY THE SOIL.

§ 3. Whatever may have been the progress of agricultural discovery, the first great business of the husbandman has been and is the proper manipulation of the land. This is what an agriculturist at once pronounces a practical branch of the subject; and probably he will ask us, with a smile, what science can effect here, where all seems to depend upon experience. I need not go back, however, upon *that* discussion. Experience is the slow maturing of wisdom, which science, dealing with principles, matures in a moment. The Chinese, who adhere to the most ancient system of agriculture in the world, expect by numerous ploughings to fertilize the soil.

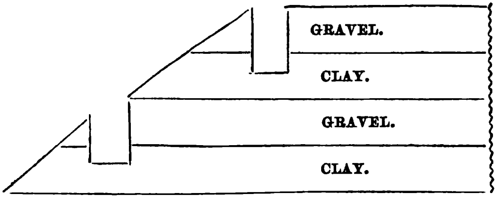
§ 4. The Romans, who farmed well, did much the same. They fallowed stiff land for two years, ploughed it nine times over, and then it yielded them immense crops. Nor was their labour light, for the Roman furrow was 9 inches deep, although what they called *scarificatio* was but stirring up the land some three inches without turning aside the furrows, before the seed was sown. Jethro Tull, the father of British Drill Husbandry, maintained also that fertility might be produced by repeated ploughings alone. The Chinese, Romans, and Jethro Tull were ignorant alike of the *rationale* of the truth they inculcated and practised.

§ 5. Science forbids us, however, to doubt for a moment the convictions slowly attained by them, and transmitted, perhaps, through generations. It assigns two conclusive reasons for the result in question. Analysis evinces the number and variety of ingredients required; whether to constitute fertility in the soil, or to supply the constituents entering into the composition of plants; and the more intimately commingled the ingredients of the soil by pulverizing, the better chance have its mutual solvents of rendering the *pabulum* it composes fit for feeding vegetation. Again, the vast amount of vegetable nutrition derived from the atmosphere, the retention of its ammonia, &c., by the alumina and some other components of soils, the decomposing influence of its oxygen, and the access obtained to the roots of plants by all its stimulating gases, when the soil is deeply and intimately stirred—declare the necessity and importance of this kind of preparation.

§ 6. But science is not content with this. It goes farther, and seeks to establish principles of permanent improvement, by drainage, by deepening the soil, and by altering its texture, rendering it friable for manipulation, and accessible to the atmosphere and its enriching contributions. Drainage is, indeed, attended in this country at least with other advantages in the preparation of the soil. Where so great a quantity of rain falls as in our winter and spring, wet undrained lands, once thoroughly saturated, require a tedious length of time to dry before being in a fit state for working upon; and, generally speaking, it is only in favourable states of the weather—early in autumn or far advanced in spring—that upon heavy lands the ploughman can attempt to compel the stubborn clod. The effect of drainage is to give access to the land throughout the winter for the exercise of the plough; not only so, but on the alluvial loams it has led to summer fallows being altogether dispensed with, and in some cases, indeed, to winter fallows also, and even to the substitution of productive stubble crops—a system the possibility of which is altogether contested by the occupiers of the strong clay farms of Northumberland, whose drainage has not yet proved efficient, else they could follow the same example. Drainage, once effected, in short, saves much of that labour which the Chinese still, and the Romans formerly, found it incumbent to bestow on their land. Silently and surely it performs the work of the husbandman, by promoting the amelioration of the soil. It even reduces the necessary amount of force required upon the farm; for the draught is rendered less stubborn to the plough, and it has been variously computed that a reduction of from 4 to 25 per cent. has been occasioned in the number of horses kept upon farms, by the introduction of drainage alone. The influence of drainage being so remarkable, it is essential to direct peculiar attention to the system as a preparative of the soil, although its ultimate advantages, it will have been conceived, are derivable from the stirring up and further manipulation for which it offers the facilities.

§ 7. The late Mr. Elkington, who, in England, is regarded as the inventor of the system of land drainage, although in Scotland there is evidence in Dr. Anderson's "Practical Treatise on Draining Bogs and Swampy Grounds"—of the precise system followed by Elkington having been previously in use, perceiving that land was frequently rendered all but useless to the farmer by *springs*, devised the means of tapping these springs where they abounded, as was frequently the case in a gradually descending surface, formed of alternate strata of clay and sand, cropping out at different distances on the slope; for he found that the sand or gravel beds, being porous, allowed the water to sink or percolate to the clay, by which it was upheld and retained, till from its accumulation it began to well out over the edges of the clay beds. Elkington having first gained a good idea of the nature of the different strata, the dip or inclination of their surfaces and their relative thickness, was frequently enabled to get rid of the water at a very small expense, by perforating the beds with a long iron dibber or fold pitcher, and allowing the water to sink into the next porous bed beneath. To this mode of tapping there might of course be no end; for he would have perhaps to repeat it on the next lower shelf of clay. But by going over the whole field, opening diagonal drains above the issues of the springs, he generally managed to cut off the source, or to lead away the water by a gentle fall into the nearest ditch. But although Elkington's system, proceeding on the principle that clay lies beneath the wet, and gravel below the dry portions of a field, and that a drain, opened above the wet place, deep enough to collect its waters and cut off their source, will cause them to sink naturally into the ground when led into the dry, succeeded in many instances, yet, as may be supposed, it was in others attended with great expense and complete failure.

DIAGRAM OF DRAINAGE.



§ 8. Observing that a great deal of money was thus expended in deep cross drains intended to carry off under water, Mr. Smith, of Deanston, author of "The Plan of thorough Drainage," directed his attention to the subject at a very early period of his useful career. In the flat clay lands of Stirling and Western Perthshire an opportunity was afforded him of witnessing the action of furrow drainage in 1806 or 1807. He perceived that it carried off the rain water which fell upon the surface; and it at once occurred to him that as the cause of cold clay soils being stiff, tenacious, and unmanageable, was the retention and stagnation of the surface water, this system of draining would relieve them of that evil. It was not, however, until the year 1823, upon his own farm of Deanston, that this able man was permitted practically to test his views, having been unable to prevail on a single holder of land to carry them out. Here, however, he pushed them to the extent of attempting a system of garden culture by means of thorough draining and deep working over a whole farm of 189 acres, to which 25 acres were afterwards annexed. It consisted chiefly of the drifted debris of the old red sand-stone, and was of various texture; some parts of the subsoil being hard and compacted with stones, and some, which lay in the hollows, of sandy clay washed in the course of ages from the higher grounds; boulder-stones, some of them very near the surface, infested the whole. The active crust of soil was very thin—in many places not exceeding four inches in depth. Rushes and water plants studded much of the surface, whilst broom, furze, and heath covered the knolls. Here was a promising spot, you would say! Yet the enterprising tenant resolved upon carrying one uniform scheme of drainage indiscriminately over its surface, at a depth of thirty inches, which he fixed as at once most efficient and economical. Over the surface of each field he laid parallel lines of drains, twenty-one feet apart, regardless whether the appearance of the soil indicated it to be wet or dry, and carried these as nearly as possible in the direction of the steepest descent, so as to bear the water quickly off, into the outfalls or main receiving drains. The abundance of stones on the surface he turned to account by arranging them, (so as to preserve the permeability of the drains,) broken to the size of a turkey's egg. At the bottom, the drains were narrowed to a cut of not exceeding four inches in width, that the confinement of the water to a narrow channel might ensure the drain being scoured of any casual deposit. The drain he filled up with stones of the size described, to the depth of 12 inches, 18 inches thence to the surface being therefore left free for the plough. It was not long ere, from a cause mentioned in my last lecture, in illustration of the relation of hydraulics to agriculture, he found it requisite to cover over the stones with a view of preventing direct access of water to the drain by perpendicular pressure. The result of these operations was a thorough and uniform dryness of surface. On attempting deep ploughing he also discovered the necessity of first employing a powerful instrument to stir up the subsoil without bringing it to the surface, or mixing it in any material degree with the active soil. You know, from one of our previous illustrations regarding the difference, for instance, betwixt the peroxide and proto-oxide of iron, that the sterile subsoil will frequently injure the productiveness of the active soil, until after having been exposed to the action of the air for several years. Now the effect of drainage and subsoiling is to admit the air underneath the surface, there to act and circulate with freedom sufficient to produce the effect of exposure; and hence the triumphs of Smith, of Deanston, in the application of drainage and the subsoil plough.

§ 9. The revolution produced by the system of thorough drainage is no less wonderfully attested by the results than by the fact that in one of our oldest agricultural writers, Captain Walter Bligh, whose third edition was published in 1652 (he was one of Cromwell's Ironsides, and favoured them with the introduction of the English system of hedging *and fencing* in more ways than one when he went to Scotland), the theory and advantages of deep drainage are enforced and explained with admirable clearness and precision, the very important practical difference between the transient effect of rain and the constant action of stagnant bottom water in maintaining land in a wet condition being clearly pointed out.

§ 10. Rain thoroughly moistens soil. The excess of moisture which the soil is unable to absorb or retain is carried below by gravitation. When evaporation takes place from the surface, a succession of watery particles is elevated from below to supply the loss by capillary action. Now evaporation from the surface commonly ceases during the night, whilst capillary action proceeds night and day as before.

§ 11. Thus it is that the hygrometrical balance is kept up, twelve hours of evaporation being compensated by twenty-four of capillary action. This provision of nature is merciful as well as beautiful; for, evaporation is a cooling process; and plants rather require warmth in order to grow; so that the stoppage of the evaporation in the night is a double advantage. This effect of evaporation is well-illustrated by the practice of putting a wet cloth in hot countries around a bottle of wine for the purpose of cooling it by the evaporation of the moisture. Thus, on wet land, the very sunshine, which occasions evaporation, must for a time be injurious to production. On a dry soil, it gives warmth and encourages plants to grow. Nor do drained lands become subject to that fearful rate of reaction which is produced by the acceleration of evaporation from the surface in the hottest months. The retentive soil, swollen by water, *then* contracts so strictly from its loss as to become inaccessible to air, from which both to obtain moisture as well as to check its own capillary action.

§ 12. Here we have the explanation of the phenomenon of soils, wet at all periods of the year except the hottest months, burning and parching then from drought. By drainage, in fact, the mechanical texture of the soil becomes altogether changed; and pulverization takes place, though more slowly, not less certainly, in the subsoil, precisely as in the freshly turned-up soil exposed to the atmosphere. We can test this fact in a moment from that of water entering and flowing from subterranean drains at all. Its doing so is quite decisive of the universal presence of air in the soil. Everyone knows that water could not flow from a tight barrel, although a spigot hole were opened at the bottom, unless air were suffered to press on the surface through a vent hole at the top. Neither will water issue from a drain laid in the earth unless under precisely similar conditions. Every drop of water that falls from the heavens displaces an equal volume of air on entering the soil; if it were not so, it would remain on the surface, as exemplified in regard to the dry earth of the flowerpot in our former lecture. In like manner the rainwater goes on displacing and disturbing air throughout its downward course till it finds its level or rest; by this action evincing that beautiful provision of nature renewing and freshening the constituent air in the soil, which is thereby filled with air, and with frequently renewed air.

§ 13. It is not always enough to view the efficiency of drainage, however, in reference to the mere descent of rain; Mr. Josiah Parkes, the eminent consulting engineer of the Royal Agricultural Society of England, mentions an interesting instance of a grass field at Strathfieldsaye, which you know was a property presented by this nation to His Grace the late Duke of Wellington, where it was supposed that drainage deeper than two feet would necessarily be ineffectual, as, at 22 inches, a bed of plastic yellow clay appeared, deemed almost impervious to water, for, cracks in it had only opened in hot seasons to 15 inches in depth. On digging the clay, however, to 4 ft. 3 in., it was found that it became of a more porous nature, and that there a mass of free water resided—that in fact, the upper clay and surface soil rested on a pillar of water, continually sucked up by capillary action, and keeping them both wet in defiance of the shallow drains. An experimental bottom drain was opened and found to discharge from the commencement a stream, averaging one gallon per minute during 76 days, or nearly 5 tons every 24 hours. The run, however, rapidly diminished, and ultimately came only to a drop. A second of these 5 ft. drains discharged no less than an area of 4,200 square yards of water 5½ inches deep. The land was now giving way to cracks to a greater depth, and an effective drainage was to be anticipated.

§ 14. Professor Phillips has analysed the clays, and found the lower more porous than that near the surface—

	Clay at 22 in.	Clay at 4 ft. 6 in.
Silica	59.	72.
Alumina	23.5	13.4

the consequence is, you may perceive, that drains could be placed wider apart in the more porous under-clay than in that above it. Beds of gravel, sand, or mixed earth, also often prevail under superficial clay, at depths admitting of drainage being made considerably wider than if the drains were formed in the clay above, effecting at once the removal of subterranean water, and a saving of outlay.

§ 15. Mr. Gray of Dilston, also testifies to an important fact in the action of deep as compared with, shallow drains: "A field 'he says' had been drained at the depth of two feet from one side to the other, still it did not produce the effect of drying the land so quickly as had been expected: the owner had a few drains cut here and there the depth of four feet: after a heavy rain, he with four others went to examine the field: they found a small run of muddy water from some of the shallow drains, but a copious one of clear water from all the deeper ones, showing that, in its descent to them, it had not robbed the soil of any of its finest parts, as was the case in the shallow drains, and that it was escaping much faster from the land.

§ 16. My friend, Mr. Thomas Scott, of 18, Parliament-street, Westminster, one of the most extensive and scientific drainage contractors in the kingdom, has collected and offered to the Essex farmers the following testimony in favour of Deep Drainage:—

Smith, of Deanston, took the system up in 1820, modifying it so far as to fix his minimum depth at 30 inches; and in 1823 he had drained 200 acres of land in his own occupation, in this way. His uncle, James Buchanan, of Careston, in Stirlingshire, had previously drained an adjoining estate of his own, 18 inches deep and 12 feet apart, the soil being a very stiff compact clay. Smith *saw* that Mr. Buchanan's land, although temporarily benefitted, was fast relapsing to its original state, and worse; he saw the same thing in Essex, and draining being repeated on the same lands, he decided to go deeper; but being more of a mechanical than a scientific drainer, having no data to help his natural sagacity, he made a mere hap-hazard guess at a depth which he hoped would ensure *immediate effect* combined with *permanency*. The effect for a few years was good, as that of *all* draining is; but the hope of *permanency* vanished at the end of 10 years, in all cases. I myself have superintended the execution of 140 miles of Deanston drainage, from 27 to 36 inches deep on stiff clay soil, all of which, within the period mentioned, has been superseded, and that at the entire cost of a tenant under a lease for 19 years, by four feet drains. The same result has taken place on estates in almost every county in England, many of which I could enumerate, if necessary; and the Deanston system, and consequently the Essex also, may therefore, as a permanent improvement, be fairly said to be everywhere "used up." Then why go back to this exploded system, seeing that there are no cases on record, out of about 2,000,000 acres drained by public and private money, of the failure of deep—that is *four* feet—drainage, unless in some special cases, where the distance has been too far apart, or the construction of the work self-evidently faulty? Again, if I am asked, why stop at four feet? the answer is simply this, that deeper drains have been cut on many estates, especially in gentleman's parks, where I have frequently cut across and down to them; but that they have always failed to dry the *surface* of the land, though they may have carried off the underground water if there was any. The reason is evident: water has a certain power inherent in its own weight, or specific gravity to overcome resistance to its downward progress and tendency to find its own level; but this has its limits, and when it is opposed by five or six feet of dense soil, aided by *its* power of absorption and retention of water and the mysterious influence called *capillary attraction*, which tends to draw all water up from its bed and send it afloat in the air by evaporation, we see that depth must have a limit. Now, it may be asked, how have we found out that four feet is the proper depth to accomplish the double purpose of *surface* and *underground* drainage? The answer is, by a long course of experiments, and by the deep scientific reasoning of Josiah Parkes,—by the fact that very deep old drains have failed to dry the surface, and that shallow drains are only temporary at best, and have never even at *first* kept the surface of the soil quite dry, the water in the drains not being beyond the reach of the influences I have mentioned. Take the following proofs:—The writer of this drained with tiles and soles 1,000 acres of a very stiff cold soil in Cheshire, in 1842, 3, and 4; the minor drains being from 27 to 36 inches deep, and the mains 4 to 8 inches *deeper*. This work was awarded, two years in succession, the drainage medal of the Manchester and Liverpool Agricultural Society. But the whole of this work has been done over again by the proprietor, four feet deep, and the land is *now* effectually dry. Mr. Legh, of Lyme-hall, in the same county, has drained 2,439 acres there, and 12,000 acres in Lancashire, in the same way, with the same successful result, and has received the same society's medal. Mr. Puller, tenant of Garswood Park farm, in Lancashire, has also drained nearly 100 acres four feet deep, and obtained the society's tenants' medal; and after repeated cropping, on a most tenacious soil and subsoil, and experiments at three and three and a half feet depths, in one of the wettest climates in England, he is also "satisfied the depth of four feet is the right one." In 1840, when shallow draining was the only system known, its rules specified the depths at from *two* to *three* feet. "*Now*," they say, "*no drain to be less than three feet six inches; and more is recommended, if fall can be got.*" William Blamire, Esq., tells me they have no record of the failure of four feet drainage under the government grant in Essex; on the contrary, the following is the general tenor of the reports sent to them:—"I hereby certify that after a careful examination of the drains and outfalls on this estate, I find that they are all in good order, and that the drainage is most satisfactory, and that the result fully answers my expectations. I have this year grown upwards of five quarters of red wheat per acre on 30 acres of the land drained four feet deep, from which I previously never had more than three quarters, and not always that." Mr. John Clutton, says—"I know of no failure of deep draining, but I do of shallow draining," that is, under four feet. Mr. Mechi says—"drains cannot be *too deep*, but they may be *too far apart*;" and he still says, in a letter to me, "I am decidedly a deep drainer." Another gentleman holding the largest farm in the county of Essex, with probably the largest capital afloat in farming, has had the whole of his farm, extending to 2,000 acres, drained 4 feet deep since 1851; and he writes me, "had I to drain my farm again, I would still put in the drains 4 feet deep." Mr. Beattie, the government inspector in the county of Aberdeen, who at one time drained 2 feet 6 inches to 3 feet deep, and found the pipes continually being filled with "iron ore," and thus choked up, has, within the last 10 or 15 years, drained 30,000 acres at a cost of £200,000, 4 feet deep, and from 24 to 30 feet apart, and finds no "iron ore" get into the pipes now, although the water falling on the surface passes off as fast as it falls. My own experience of 10 years is, that deep draining accomplishes all we require. I say this, after having deep drained 15 different estates; on one of them 2,000 acres, at a cost of £10,000; and having previously cut upwards 300 *miles* of shallow drains on other estates, all of which gradually failed. Mr. Hobbs completely thorough drained the whole of his farms at 4 feet and upwards, ***not having put in a single drain at a less depth.***

§ 17. It is still, it would seem, a question with some agriculturists whether to drain or not, and Mr. Hewitt Davis, a practical English farmer, says:—"Before draining, examine your land by sinking little wells 4 or 5 feet deep, and if you find a porous substratum that allows water freely to pass down," [I have shown that interchanges of air in that case inevitably occur, and you are not shown that water rises in winter,] "*do not drain*, for no benefit can accrue therefrom." On the limestone gravel, in many parts of Ireland, this is peculiarly the case. It is needless to drain, but it should invariably be kept in view that it is erroneous to regard drains as intended to carry off the surface water. No rain water should ever be suffered to pass off the ground in that way; it should be conducted *through* it, and it is the object, alike of drainage and tillage, so to do. Rain passing through the soil to the depth of 4 feet raises the temperature of the soil in its passage; but if the soil be drained to the depth of only 2½ feet down, as we mostly see it, water is soaking upwards and not downwards by capillary attraction, constantly passing off by evaporation, and the extreme cold of the spring is thus too bitter for the tender herb. In the formation of a drain an even current, with the greatest fall, will secure permanent flow and washing of itself clean.

§ 18. A geologist would also incline to cut his drain across the lines of strata, so as to let out the water that lies between. Drains are to be made, if possible, in the winter and early spring to prevent interruption of other farm work.

§ 19. The number and position of main drains being regulated by the nature of the surface, they are cut several inches deeper than the small drains to afford the water from these a sufficient fall, and by the common practice of the country (for drainage is not in general nearly so deep as it should be) are generally from 3 to 3½ feet deep and from 15 to 18 inches at bottom, and a proportionate width at top. This depth of mains corresponds well enough to branch drains of 30 to 33 inches. An eye or open conduit of stone is generally formed in the bottom of the main drain. Common drains are now laid down the slope in parallel lines at intervals of 17 to 30 feet, according to the texture of the soil and subsoil.

§ 20. In Aberdeenshire, stones are still used almost exclusively for filling drains, broken, according to the Deanston plan, to the size of road metal. The practice is to open the drains at the lower, and to commence filling them in at the higher level to facilitate the escape of water. Latterly there has been a tendency both to lessen the size and the quantity of stones filled into drains. Mr. Smith regarded 4 or 5 inches of broken stones as enough. A turf of 2 inches thickness is then laid over the stones, with considerable care, to prevent the direct access of water, as already said. For, the difference in the action of rain on the soil as produced by drainage is just this, that when rain falls with great force on undrained land it washes away with it those valuable finer particles of soil, which, owing to drainage, are now left in the soil itself. A portion of the most tenacious subsoil is even well trampled in with the feet or beaten down with a wooden instrument; the remainder of the earth is put in sometimes with the plough—and various ploughs have been invented expressly for filling drains—but generally with the spade, and the surface is rubbed over, as a finishing stroke, with a turn of the harrows.

§ 21. Besides stone drains, turf drains have been successfully formed, and numerous tracts of peat-moss drained by their own material, at an expense not exceeding £1 an acre. Even wood drains, the thinnings of plantations, have been employed where stones are scarce and wood is cheap, and I know of no better substitute for the soles employed along with tiles than the wooden slabs of timber trees. But the drains which are now easiest of construction, and consequently cheapest, while they are undoubtedly best, are tile drains—formed either with tiles of a horse-shoe shape, and flat slate or tile soles laid under them—or of entire pipes—laid perfectly level along the bottom of the drain. The cost of these is only from 16s. to 20s. per thousand feet.

§ 22. The general recommendation is made by all practical improvers to lay the land perfectly level after thorough drainage. From Mr. Smith to Mr. Mechi, all have proclaimed that wherever the land was drained it was necessary that the high ridges should be done away with and the land laid down perfectly level—Mr. Smith to obviate the washing out of the valuable constituents by the immediate rush of surface water without percolation, and Mr. Mechi in the idea of having a fairer area for operations laid out before him. Mr. Parkes also, though not a practical farmer, confidently recommends to farmers the laying land absolutely flat after efficient drainage. "It is the practice," he says, "of many good agriculturists on the stiffest clays, who consider that even a crease left on the surface is injurious." Such, nevertheless, is the ignorance and absurdity with which the system, now so largely developed over the country, is followed out, that sometimes we may see, after thorough drainage, the land ploughed no deeper than before, and with rounded ridges—counteracting the entire scheme—for land is no longer drained upon the surface, which it was the object of ridge and furrow to effect—the concave furrows and rounded ridges are no longer suffered to carry off, in floods, the richest parts of the inclined fields; but the land is now drained *under* the surface, expressly to remove these ridges and furrows, and to obviate the loss they occasioned—to *prevent* water running upon the surface—to enable every part of the soil to absorb and filtrate the rain which falls upon it, and thus to pass off by percolation, all except the surplus and sediment it retains in mechanical suspension.

§ 23. The next stage in the preparation of land after drainage is that important step which renders drainage most available—subsoiling. It must be observed, however, that to enable the subsoil to become somewhat ameliorated, and to work more kindly, as well as that the covering over the drains may become consolidated and proof against injury, it is the practice of the more cautious agriculturist to subsoil only the third year after drainage, in the idea that then only can it be begun with advantage. But the subsoil plough is only intended to break up the subsoil without bringing its materials to the surface—to promote only or accelerate that chemical action which drainage itself is more slowly facilitating. And as it is one of the best maxims of agricultural improvement, that it will be found more advantageous to proprietors, and will always impose less annual expense and risk on occupiers, to employ capital in reclaiming depth of soil, rather than area, although both are desirable—in fact, as according to Dr. Samuel Johnson's dogma—whatever is worth doing at all, is worth doing well; therefore, on with the subsoil plough as soon as practicable, and deepen away! This implement is worked *across* the lines of drainage—or of common ploughing operations, because, in the latter, the close earth below the furrows is sometimes trodden by the horses into a state impervious to water. Its great and important use is, therefore, that of breaking through the close earth into a stratum more porous. By crossing the tile drains in wet lands, it is calculated to cause the surface water to be carried off within a few hours, and to relieve the earth of stagnant moisture, which has sodden it perhaps for months. Where the subsoil plough is intended to be employed, the expense of tile draining may possibly be lessened, therefore, by placing the drains farther apart, although this is only to be done with caution, as it is now seen that Mr. Mechi's far-apart drainage, on Tiptree Farm, is very inefficient; but in his famous balance-sheet I find a considerable sum set apart for a new Branston's plough, and probably by its means the Tiptree drainage, which is 5 feet deep, may have begun to act better.

§ 24. The cheapest manner of subsoiling is to employ four horses, attaching them successively first to the common, next to the subsoil plough, taking alternate rounds along the same furrow, and penetrating together to a depth of not less than 16 inches; this arrangement is recommended by Mr. Simon Hutchinson, the Lincolnshire drainer, in his practical treatise "On the Drainage of Land, on Hydraulic and Pneumatic Principles," to small farmers, because they would not have to provide an extra number of men and horses; and where the ploughs are separately horsed, the common plough, owing to the slower progress of the subsoiling implement, has more than the necessary time for performing its less obdurate operation. He recommends, however, where the two ploughs are thus to be kept going alternately, that the "break" as he calls it, that is the means of adjusting the diagonalism or twist of parallelogram of forces composing the *draught* of the common plough, should admit of the plough being thrown sufficiently from land, and as I take it somewhat on one side of the horses, that they in drawing it may be kept out of the furrow; this is necessary to avoid again treading down what has been lightened by the subsoil plough.

§ 25. Drainage and subsoiling are, of all modern agricultural processes, best calculated to show us what we have gained in agricultural knowledge over all ancestral times. Until their introduction, cultivation dealt only with the active soil. The subsoil, to use a harsh word, and I suspect an Americanism of the day—it *ignored*. But there is truth in the converse of every proposition—drainage which throws lands into cultivation—long neglected, would throw them out of it. There is a passage in Johnston's lectures, written just before the full importance of this initiatory improvement became impressed upon the agricultural world, in which the writer ascribes the origin of many of our moor lands, especially on higher grounds, to the lingering of unwholesome waters beneath. "A calcareous or ferruginous (limy or iron) spring sends up its waters to the subsoil." The slow action of air from above, or it may be the escape of air from the water itself, causes a more or less active deposit—for you know if there be sulphate of iron in the water, peroxide will be produced by the oxygen from above—or if bicarbonate of iron or lime there will be an escape of carbonic acid, causing a deposit of carbonate of lime or iron—and any of these deposits will cement the earthy or stony particles together. "Thus a layer of solid stone," says Johnston, "is gradually formed—the *moorland pan* of many districts—which neither allows the roots of plants to descend, nor the surface water to escape. Hopeless barrenness therefore slowly ensues. Coarse grasses, mosses, and heath grow and accumulate upon soils not originally inclined to nourish them, and by which a better herbage had been long sustained." Johnston even warns us that in many tracts which have been improved by the breaking up of this moorland pavement, unless accompanied by sufficient drainage, the same natural process will again begin, and the same result will follow, unless an outlet be provided for the waters from which the petrifying deposit proceeds.

§ 26. On the other hand, an outcry has been raised in many districts that land has been over drained; and that hence the pastures have been spoiled. When I first heard this, it was from the lips of Mr. Smith of Deanston himself, at Aberdeen, and he seemed to attach to it an importance for which it was difficult to account. He said that the fens in Lincolnshire had been drained too deeply, and that to preserve the pastures it had been found requisite to let the water on again at a certain depth. Another of his name, however, Mr. Robert Smith, in a prize essay on grass land in the 9th vol. of the Royal Agricultural Society's Journal, has denied that this injurious inference is applicable to drainage, the soil being changed for the better. The food of the aquatic grasses having been removed they become dry and inactive. To misappropriate an ancient Border saying, "the rush bush" is no longer made "to keep the cow." That, you know, was the boast of one of the James's when he hanged Johnnie Armstrong and the border thieves. But there is no longer a rush bush to perform any such office; where improvement makes its appearance the rush bush is an opprobrium—a reproach: "It is true, however," says Mr. Robert Smith, "the existing grasses become more like stubble than grass." But he adds, "having so far changed the soil, it is equally necessary to change the herbage by other agents—such as suitable top dressings to sweeten and increase it." The pasture then becomes gradually improved, and nature supplies her indigenous grasses, the exquisite white clover, &c., suitable to the improved character of the soil; whilst the aquatic or other spurious, and let me add, *poisonous* grasses, in the absence of *their* food, decline and die out.

§ 27. There are a good many arguments in favour of deep cultivation, of which subsoiling is the first course and drainage the foundation. The difference of vegetation on cultivated and uncultivated land is sufficiently remarkable; the crops and produce of the deeply cultivated gardens, as contrasted with ordinary tillage crops, equally so. What causes the difference? Is it not manifestly proportioned to the depth of cultivation? And why should deep culture not be prosecuted? The same original materials composed both soil and subsoil—the sole difference arising from the one having been stirred by the plough, having become or remained accessible to the fertilizing influences of the atmosphere, which Mr. Parkes somewhere calls "nature's grand storehouse of manure," purified of noxious principles, deepened and made productive. The worst lands have been made productive by trenching and mixing.

Trenching, as you are aware, is the foundation of all garden cropping, and the deep artificial garden soil always admits of that operation, whereby three or more spades deep of earth are removed and interchanged. But it has been remarked that this process, applied to the best garden ground and the worst waste land, has been neglected in the case of the superior arable lands of this country, which have never been moved beyond nine inches deep, the ordinary depth of a plough furrow! A practical essay, written by Mr. Henry Stephens on "Deep Farming at Yester," was recently published by the Marquis of Tweeddale, to show that double or treble that extent must produce larger crops and bring good lands to the highest pitch of their fertility. Nor can it be doubted that the limits of quantity in agricultural produce are far from being reached. Palestine, and some southern countries yield a hundred fold and even more. In Sir Gardiner Wilkinson's Topography of Thebes we have a statement respecting the cultivated plants of Egypt, in which the returns are even larger, and certainly quicker, whether in the winter or the summer cultivation (for they have both). But it has been justly said that the British farmer would be thankful if, with all the aid of science, he could reap fifty after one. The preliminary drainage improvements having been so extensively effected, why should not the deepening of cultivation keep pace with the new opportunity of increasing our produce thus afforded? The Flemings, who have derived from long experience much of what we are now beginning to attain from scientific disclosures, have a custom of annually digging, at intervals, the bottoms of furrows and laying the fresh earth on the surface. But how much less effective is this *petite culture* than the systematic subsoiling of every furrow, you are by this time in a position to judge. All naturally rich soils are deep, and composed of a variety of constituents intimately blended. Subsoiling, and deep cultivation following it up, at an interval regulated by the nature of the materials, (for the geological facts must be kept in view) merely copy nature in this respect—moving and mixing a greater bulk of materials—bringing new earth into action, making valuable additions to the soil. The chemical effect of this admixture is to bring mutual solvents into contact, and liberate long dormant gases and principles to nourish vegetation. Take the case of pure clay and pure sand. Apart and unmixed, each is he extreme of barrenness. But intermixed they constitute a fertile earth, the silicic acid and other properties of either becoming active; and even the new mechanical texture of the composition enabling heat and moisture to be absorbed, retained, or parted with, precisely as required by plants.

§ 28. So fertile sometimes are soils whose ingredients are thoroughly intermixed that Bakewell mentions, "on the summit of Breedon-hill, in Leicestershire," having seen "a luxuriant crop of barley growing on land that had borne a succession of twenty preceding crops without fallowing or manure."

§ 29. Mr. Smith, of Deanston, declared before the Committee on Agricultural Distress, in 1836, that he had employed his most formidable invention, the subsoil plough, through a first rotation on the farm of 200 acres already mentioned, and on beginning a second, he ploughed up the previously stirred subsoil, whereby the produce of oats was increased from 24 or 30 bushels of oats per acre, to nearly thrice these quantities, superior in quality, and the rented value of the land raised from 15s. to £2 sterling. Such immediate effects are not always to be expected from subsoiling, which, as we have been careful to show, is a mere preparative for deepening the cultivation, as drainage itself is for subsoiling. The full benefit cannot be obtained till the loosened soil is fertilised and rendered capable of being ploughed up and mingled with the active crust.

§ 30. The late Mr. Murray, of Polmaise, introduced a practice which he termed winter fallow, for it produced a crop, and was thus preferable to vacant summer fallowing of land, a resource reverted to, as we have seen, in the absence chiefly of the mechanical improvements we are this day discussing. At the removal of the crop he drilled thorough drained land at right angles to the drains with the common plough, and subsoiled the space between the drills. He split these drills in January, and then subsoiled the spaces on which they rested. A seed furrow afterwards levelled the surface and completed the preparation for barley or other spring crops. The object of this operation was to keep dry tenacious lands, expose a greater surface to frosts, pulverize and mix the most stubborn materials, throw out the weeds, afford uniform depth and fertility of soil; and, instead of the unequal growth seen on crown and furrow, a luxuriant crop ensued, covering the surface equally over. It is much in favour of deepening our ordinary cultivation that manure put into a deep furrow is certain to reach the plant, whose roots will either descend to it or its influence will ascend to them. Lord Kaimes has a strange observation regarding churchyards, in which he notices that the earth is only enriched upwards. In fact, the levity of the gases of decomposing substances compels them to ascend. In like manner the very atmospheric action being deepened in the soil—if the atmosphere be (as every one who studies the provisions of nature and contemplates the extent and abundance of leafy surface spread abroad by the humblest flower or the largest tree to catch its influence, must acknowledge) an inexhaustible magazine of vegetable nutrition, this must promote the progress of plants.

§ 31. There are various prejudices against pushing these advantages fairly to an issue—the first is derived from the experience in deep ploughing undrained lands. This has been found to prepare a lodgment for water which has no outlet: but this it is the very business of drainage to cure. The second is derived from experience in subsoiling itself—as ploughing down the soil and up the subsoil is certainly attended with a temporary loss of fertility; but the precautions employed in subsoiling, of stirring the subsoil without bringing it up, and maturing it where it lies before bringing it into use, remove this obstacle also. A third obstacle comes under the head of a besetting sin—for it is nothing but indolence—an apprehension of the severity of the work for man and beast; but even this our improvements go far to modify, since the soil, rendered more friable and easy in working, will become more so as manipulation proceeds. Such has been the influence of these miserable obstacles that the railway sections all over the kingdom have disclosed nothing more striking than the depth of our soil and the shallowness of our cultivation. If I were drawing you a rhetorical sketch of our agricultural deficiencies, no more ample scope could be found than in what is here exhibited for denouncing our whole operations, as characterised by a wilful improvidence and rejection of the bounties of nature and of God. Here lies the thin stratum of cultivated earth, tortured and exhausted by the extraction of all manner of crops, and, underneath it, depths of fertile substrata, not only untouched but walled down by the beaten road, which the long and exhaustive operations of husbandry carried on above it, have trodden so as completely to cut off its benefits!

§ 32. Plants themselves send down their roots naturally to a depth which, strange to say, is so little known as scarcely to be credited. In the case of beans, turnips, and red clover, we are familiar with the fact that their roots penetrate to double the depth of ordinary ploughing; we raise up the turnip on drills to help it, and we expect the pulse and grass crop to perforate and deepen the soil to help us. But there is not a cultivated plant which does not *naturally* send down its roots beyond nine inches. The cereals on which our agriculture mainly depends are indeed endowed with the power of forcing their roots deep and far into the solid earth in search of food—and, as the investigation of drainage obstructions has lately evinced it inconceivable by any process short of actual tracing to fix the distance to which the roots of trees and hedge plants will penetrate, so is it found that wheat and our other cultivated grasses extend their roots much farther into the soil than is at all generally supposed. Johnston, in his drainage lecture, says that deep-rooted plants, such as lucerne, often fail, even in moderately deep soils, because an excess of water or the presence of some noxious ingredient which deep drains would remove, prevents their natural descent in search of food. "Even plants," he adds, "which, like wheat or clover, do not usually send down their roots so far, will yet, where the subsoil is sound and dry, extend their fibres for three or more feet in depth, in quest of more abundant nourishment." But, I repeat, it is not thoroughly understood how deeply the roots even of wheat and clover descend. The Earl of Macclesfield, in a letter to the Society of Arts, mentions that a few years ago Mr. Badcock, a shrewd, sensible, observing, and very considerable farmer at Pyrton, Oxon, having occasion to dig the foundation of a building in a field under wheat, was much surprised by observing the small fibres of the roots of the wheat much deeper in the earth than he had any idea of. Endeavouring to trace how deep they really went, he had the ground opened close to some plants, dug perpendicularly down to the depth of six feet; and having fixed a narrow board close against it, proceeded in the same manner on another side of the plant, and so on, till he had secured the earth to that depth between four boards firmly lashed together. He then had it placed upon an inclined plane, and carefully removing the boards, with great caution and perseverance washed away all the earth adhering to the root, and its very small fibres, and was much surprised at their extent. He repeated the trials on several other wheat plants, and traced their depth to between five and six feet. The late Mr. Fane, M.P. for Oxfordshire, had one of these plants, now presented by Lord Macclesfield to the Society of Arts, secured in a close glass tube. My friend Dr. Atkin and myself have traced the roots of wheat in Berwickshire to five or six feet.

§ 33. Ploughing, the most common, is still after all the most important of agricultural operations.

§ 34. The latest *desiderata* of Scotch ploughs, as set forth in the premium list of the Highland and Agricultural Society, is the construction of a plough best adapted to produce in the first place a furrow slice which, before being turned over or broken, shall contain the largest transverse sectional area, or the greatest cubical contents in a given length; and, in the second place, have the lightest draught in proportion to the cubical contents of the furrow slice. A note to this item of the premium list informs us that a question arises, on which it is understood there exists also at present much difference of opinion, namely, which of the two distinct varieties of ordinary two-horse ploughs is the best construction of plough for general use—the one distinguished in the external character of its work, by cutting and setting up the furrow slice with a sharper shoulder than a right angle, or the other distinguished by setting it up with a shoulder not flatter than a right angle. How this knotty point may be answered I am not prepared to say; although I have always seen the best practical men in a ploughing field point out to the furrow slices, which were cut to the sharpest points, turned up perpendicularly and pressed most compactly together as being the best work. I am not in this lecture to speak of implements so much as of their work; and although the plough is that weapon with which the producer must henceforth fight his country's battles; although it has marked the progress of civilisation by its vast and varied transformations from the forked and ragged branch of a tree, snatched up by the untutored Pagan, to tear asunder the clod of the valley, down to the last prize implement, with its case-hardened shares, wheels, and patent trussed iron whipple trees. I must pass it over by remarking that whilst in Kent they still obstinately adhere to the old wooden plough, inflicting a mere scratch upon the surface, and whilst the Americans, on the other hand, who boast that all their labour-implements are simpler and more effective than our own, appear to have come off best at the great comparative trial of implements at Windsor, in connection with the Great Exhibition of 1851—there is nothing, in my estimation, comes up as an implement in skilled hands to the common swing plough.

§ 35. Our English ploughs are mostly distinguished by being lighter and more slender in their formation, and by being commonly used with a guide-wheel, or perhaps two—a larger and smaller—the one to run upon the furrow (that is the larger) the other on the unploughed land. Upon level land the ploughing is certainly regulated with greater certainty, both as to width and depth, by the use of one wheel, or two, than when the plough is used without a wheel. But does not this very regulation debar the exercise of *skill*, by means of which those using the swing plough invariably make up for the want of a wheel? The powers thus taxed, we hence see better ploughing produced without the wheel than with it—because it is in the one case the production of skilled labour—in the other it is not.

§ 36. Draining and pulverization having reduced the soil of a farm, even though originally somewhat stiff, to a uniform friable texture, suppose we now run over the various preparations to be undergone in a long shift or six-course rotation of the most improved farming, as followed in the famed East Lothian? For a FIRST COURSE OF OATS we would have to plough, probably in February, that division of the farm under the first of our rotation. A furrow slice 6 inches in depth, by 9 in width, with 18 feet ridges, to mark out a convenient breadth for hand sowing, to enable two pair of harrows to cover the seed in, and three people to reap abreast in harvest, would be about the ordinary rule. But you know we point at the total suppression of ridges; and would, moreover, prefer sowing and reaping too with a machine, for reasons which need not at present be discussed. The seed time is from the middle to the end of March for oats—a difference of a bushel per acre being perceptible between March and April sowing. The land after sowing must be perfectly harrowed and pulverized. To this some have added drilling—but it is doubtful, in the oat crop, if more produce is raised in rows than in even sowing over the surface. After sowing and harrowing, however, it is good to roll the land with the double-horse roller, (with which all are familiar) particularly in dry weather—the operation not only smooths and consolidates the surface, but tends to produce a more regular braird, and to afford a more perfect application of the scythe, or reaping hook, or reaper. If the land has been properly managed, weeding in spring or summer will be unnecessary—but should weeds appear, the farmer ought to be instructed to apply the hand to clear them off, for it will never do to have to encounter the ridicule to which Mr. Mechi, in his balance sheet phamphlet, lately records a farmer to have been subjected, of mistaking a corn field for an excellent crop of wild mustard—the yellow flowering *sinapis arvensis* so plentiful in oat fields; women may be employed to clean out such weeds at no great expense.

Potatoes or Mangel Wurzel manured succeeding oats as a second course, as early as possible after harvest the stubble break is ploughed down; it is then that a subsoil ploughing should be given — the two-horse plough being followed as before described by the subsoil plough, drawn by four horses stirring up the subsoil without materially mixing it with the upper stratum. The land remaining in this rough state all winter, frost and other ameliorating agencies freely penetrate it, and greatly conduce to its productive power. In March and April the harrow, plough and grubber must all be applied to cleanse the ground, and weeds and stones gathered and carted off till it is perfectly clean and pulverised. It will then be ridged up in drills 27 inches wide, and manured with animal and vegetable matter from the dung heap, at the rate of from 30 to 40 tons per Scotch acre, according to the quality of the soil. The sets are planted as fast as the manure is laid out, the drill plough at the same time reversing the drills and covering both seed and dung immediately afterwards. This, if performed by the double mould-board plough, will be finished in half the time required by the common plough, with only one mould-board. In about 14 days the drills should be harrowed lengthwise by a pair of light curved harrows drawn by one horse. This operation, repeated three or four times till the plants appear above ground, will partially level the ridges, and destroy the annual weeds on their first appearance. The horse-hoe and hand-hoe must then be kept in constant requisition until the plants are far enough advanced to require earthing up, which may be effected by the double mould-board plough with two horses. Mangel wurzel is an excellent preparatory crop for wheat, not requiring to be sown before May, and therefore leaving ample time to cleanse and pulverise the ground. The preparation of the land for beet of any kind does not differ materially from that for the potato—the stubbles being subsoil-ploughed early in autumn, and in spring minutely cleaned and pulverised. In May the land is at once ridged up in 27-inch drills—which admit the dung carts without destroying the ridges, are suited to the action of the horse-hoe for summer cleaning, and leave room for expansion of the leaves. Decomposed animal and vegetable matter being again applied at the rate of from 30 to 40 tons an acre, and spread out regularly, should be speedily covered in by reversing the ridges, and a light curved roller passed smoothly over these to consolidate their surfaces. The seeds put in by the dibber will be most correctly deposited, and five or six women will complete an acre in a day. The dibber is a crude pointed implement, which should have a cross-piece of wood fixed two inches from its point to prevent its penetrating deeper, as the seed, whilst requiring that depth of covering, will not vegetate farther below the surface. The length of the dibber is also a guide to the intervening distance between the plants. The women carry the seed in their aprons, and depositing three or four in each hole, slightly cover it in with the point of the dibber, the subsequent passage of the roller closing it over more effectually. Four or five pounds of seed will thus suffice for an acre. A running drill will, however, deposit in the same space double that quantity, and will consequently increase the subsequent cost of thinning. Shortly after the appearance of the plants, the hand-hoe and horse-hoe are to be applied, and perfect cleansing effected without wounding the plants, which seldom recover injuries now inflicted. The THIRD course, WHEAT, is divided both into autumn and spring culture, or winter and spring wheat—the former being the more regular crop; the latter, which for many and obvious reasons, obtains the farmer's preference, being merely a change of habit in the winter variety. The land, when cleared of the fallow crops (potatoes or mangel), is to be well harrowed, both lengthwise and across, the remaining leaves, stalks, or weeds to be gathered and carted off—next to be laid out in ridges 18 feet wide, and ploughed in as perfect a manner as possible, with a furrow of 9 if possible, and not less than 7 inches in depth, that being indispensable. The wheat being properly pickled to ward off smut and other fungoid diseases to which it is incident, may be sown broadcast or drilled. Well-farmed wheat land seldom requires summer hoeing, and the broadcast system is practically considered to produce a larger crop than the drill. From three to three and a half bushels of seed suffice for an acre, or less for early sowing, when the plant has more time to tiller or stool. After sowing, the harrows are put in motion, both lengthwise and across, till the seeds are well covered and the ground perfectly pulverized. The practice is then to water-furrow it lightly and clear out these runs with the spade. I have shown the absurdity of this in the teeth of thorough drainage, but it is done. To promote the progress of tillering, the land may again be stirred with the harrows in the spring, and subsequently consolidated by the roller. The FOURTH, or TURNIP COURSE, along with which some would introduce CARROTS (a good crop not sufficiently appreciated), may commence by the land being limed with shells after the removal of the wheat, at the rate of thirty bushels an acre. Lime rapidly sinks into the soil, and should, therefore, be applied to the surface. Carted to the farmstead during summer, the limestones should have been mixed with an equal bulk of earthy matter, couch grass, weeds, road scrapings, ditch scourings, earth and roots from headlands and old hedgerows. This light mixture of earthy matter will admit of the superficial application of lime to the land, which is again to be subsoil ploughed, the two-horse plough preceding the four-horse subsoil one immediately after harvest, and as the land is dry there is little difficulty experienced in carting on the compost.—Lime, when used alone, is applied on the stubbles and ploughed down with a light furrow; and although the subsoil plough follows, it will not bury the lime any deeper, as it merely stirs the substratum. The use of the compost keeps it near the surface, and there is always something beneficial in applying extraneous earth. The lime is not applied to manure the turnip or carrot crop, but to ameliorate the land for next rotation. Carrots are manured with about thirty tons per acre of farm-yard dung, laid on the stubbles and ploughed in to prevent waste; but turnips are not manured till spring; and the land in both cases lies over in rough furrow till the earlier spring crops are sown. It must be remembered that the long fusiform root of the carrot demands a great depth of soil, and the subsoil ploughing will give it, to any of medium quality. Before the end of March the land should be well harrowed, and at every interval of harrowing, (for it must be repeated once and again,) every vestige of weed gathered off. During April the land will be ridged up in drills, 18 inches apart, by the double mould-board plough, and slightly compressed by a curved wooden or cast iron roller, covering four drills at once. The carrot drill machine may then be employed to deposit seeds along the ridge at an inch deep, and the roller passed over to smooth, consolidate and finish. The hand hoe is set to work as soon as the young plants are seen. In two or three weeks the thinning process is completed; but the crop, which ought to be kept free of weeds at all periods of growth, will still ask two or three hoeings and weedings. The latter end of May or beginning of June is the proper season for sowing the turnip—the Swedish requiring to be sown first, the hybrid next, and lastly the common turnip. The thorough preparation of the land must be undertaken not only with a view to this important green crop itself, but to that which is destined to succeed it in the rotation. Keeping in view, then, the subsoiling and liming, and the leaving over of the land in rough furrow throughout the winter—early in April it is to be well harrowed, then ploughed across the former ridges, harrow, plough, roller, and grubber, succeeding one another till they achieve a perfect pulverization—weeds and other obstructions disengaged from the soil in these operations being scrupulously removed. The land, when reduced to the fine tilth demanded, is formed into drills by single bout ridgelets—these drills, 27 inches apart, freely admitting manure carts, horse hoes for summer culture, and the circulation of air between the rows. Thirty tons for Swedish, or twenty-five tons for other descriptions of turnip, of well prepared manure, are now applied per acre. Heaped into the hollows of every fifth drill, at 9 feet intervals, this manure is spread with light three-pronged forks, and lightly covered in at once by the double mould board plough, which splits each drill down the centre, and thus forms a new drill over the hollow where lies the dung. The sowing by double-drill sowing machine proceeds daily with the other work. The single-drill machine is less expeditious, but more common on small farms. Bone dust, or any portable manure, is best applied by the drill along with the seeds—the apparatus attached for that purpose placing the manure a short distance under them. About 4 lbs. of turnip seeds are required per acre. Hoeing commences when the young plants are about an inch in height. After the horse-hoe has passed through them, they will be in rough leaf, perhaps, and ready for thinning, which is performed by the hand-hoe, and the plants singled at 9 or 10 inches distance. In a few days, more weeds again spring up, and the horse-hoe is applied, followed again by hand-hoeing and singling any plants left double, leaving the strongest. Hoeing is repeated at intervals till the overshadowing leaves of the plants keep down weeds. The FIFTH COURSE of BARLEY with GRASS SEEDS commences by harrowing well the former drills, as the turnip or carrot crops are cleared off the lands, and not only levelling them, but diffusing their rich soil over the undunged intervals, gathering off weeds, fragments of turnip-tops and carrots, because they might grow with the next crop and cause trouble. The land laid off in the established 18 feet ridges, is ploughed with a strong, deep furrow, and water furrows cleared out with the spade to facilitate the escape, as farmers allege, although we repudiate the doctrine, of heavy falls of rain or rapid thaws of snow, which it is held no drains can absorb; and if it be so, so be it. Stagnant bodies of water, however short may be the period they remain, are, unquestionably, deleterious to the soil. The land remains thus till the middle of March, when it is harrowed, cross-ploughed, again harrowed, then grubbed across the last ploughing, all extraneous matters being once more carefully gathered off. Thus, in most cases, it will be reduced to a fine tilth, and be in condition for the seed furrow, the influences of frost and atmosphere having by this time much ameliorated it. On very stiff land indeed additional work may be necessary, for the success of barley with grass seeds intimately depends on perfect pulverization. The land will, therefore, now be laid off in the 18 feet furrow ridges, correctly ploughed with as light finishing furrows as possible—but of depth sufficient to mark the division betweeen the ridges, and assist the drains in running off extra falls of water. The seed should be sown as early in April as possible. Early barley has the best chance of fine quality, late is never very fit for the maltster, and will not satisfy his eye by the much-desired criteria of plumpness and thin shrivelled skin. Four bushels of seed are required per Scotch acre. The broadcast machine will distribute it most effectually. Harrows follow, the machine giving the land a double turn lengthwise, and the same along the ridges; or if not sufficient, a second double turn lengthwise. Immediately after these operations a careful mixture of artificial grasses is sown by machine 45lbs. per Scotch acre. covered by a double turn of the harrows, and the operations concluded by rolling with a single horse roller to compress the soil and exclude drought. There is no summer culture. For the SIXTH COURSE, sheep with their golden feet and enriching presence may be let in to depasture the YOUNG GRASS—but no cattle, save, perhaps, quiet milch cows. As early as dryness will permit, the grass is to be treated with soakings of liquid manure till first cut for soiling early in May. The portion reserved for hay being similarly treated till cut, when the plants are in full flower.

Such is a programme of those operations in husbandry, which, in a full six-shift course of improved agriculture are requisite for the preparation of the soil alone. The labours to be undergone are neither few nor small. Far from diminishing the farmer's toils, those magical means and golden visions which science shows him in the valley of futurity are thus fully blended with increased measures, as they are gilded with increased motives of exertion: and we still require to quote to him the admonition of Solomon—"The sluggard who will not plough by reason of the cold, shall beg in harvest and have nothing; but he that tilleth his land shall have plenty of bread."

INCIDENTAL QUESTIONS.

1. Commencing with Highland and Irish crofters, what farm limits are the lowest for supporting families on small holdings?

2. Mention the more prominent experiments in cow-keeping, school and spade farming, of late attempted?

3. Why is the Belgian system of *Petite Culture* unsuited for our remoter districts?

4. What would be the probable effect of better agricultural instruction?

5. What is, in fact, the chief object of sound husbandry?

6. What is the first object of the husbandman in the preparation of the soil?

7. By what means do the Chinese impart fertility?

8. How many ploughings did the Romans give the land, and with what result?

9. State the depth of the Roman furrow?

10. What did the Romans call *scarificatio?*

11. What doctrine respecting ploughing was held by Jethro Tull, and who was he?

12. How do we know, in the first place, that soils should be commingled in fertilizing them?

13. How do we learn, in the next place, the propriety of their being deeply stirred and exposed to the atmosphere?

14. What permanent improvements are contemplated in thus handling the soil?

15. State the first and most obvious benefits of drainage in a wet climate like ours?

16. How does drainage effect a saving of labour and of draught power, and to what extent?

17. Are there any evidences of drainage schemes prior to Elkington?

18. What term is applied to the system employed by him?

19. How did he work it out?

20. Was Elkington's, then, a partial or a thorough system, and to what extent did it succeed?

21. Who was the author of "The Plan of Thorough Drainage"?

22. Where and when did Smith, of Deanston, commence operations in drainage?

23. On what size and character of farm did he attempt garden culture by means of thorough draining and deep working?

24. How did he construct his drains?

25. Did he study to prevent *direct* access of water to them, and with what result?

26. How was the subsoil plough first suggested to his mind?

27. On what principle is the subsoil exposed to atmospheric action—openly, or by admission of air?

28. Mention an old English author who enforced the theory and advantages of deep drainage in 1652?

29. What is the action of rain on soil, and the ordinary processes by which its removal is effected in a state of nature?

30. What is the state of the hygrometrical balance betwixt evaporation and capillary attraction in the soil?

31. Is evaporation a cooling process, and how illustrated?

32. Do plants require warmth?

33. Whence, therefore, the advantage of the above arrangement or "balance"?

34. Explain why rapid evaporation is injurious on wet lands, and what sort of reaction it occasions on retentive soils?

35. What change of mechanical texture ensues from drainage?

36. How do we know that it admits air into the soil?

37. How does water find its level when there is air in the soil?

38. What were the nature of Mr. Josiah Parkes' deep drainage experiments at Strathfieldsaye—give the details?

39. In what proportions are clays more or less porous at various depths, according to Professor Phillips?

40. Under what conditions may deep drains be made wider apart than shallow drains?

41. What difference did Mr. Gray, of Dilston, discover in the action of deep and shallow drains?

42. Mention the leading testimony in favour of 4-feet drains adduced by Mr. Thomas Scott?

43. State, on the other hand, why the recommendation not to drain at all is made by Mr. Hewett Davis, and under what circumstances?

44. Why should rain never pass off by the surface?

45. What benefits result from its being conducted through the soil?

46. Does the temperature of the soil rise or fall from rain passing down through it?

47. Does the temperature fall or rise from water soaking up through it?

48. What direction of drain will secure its permanent flow and self-washing?

49. Why does geology suggest that drains should be cut across the strata?

50. At what season should drains be formed, and why?

51. What are the main drains—how much deeper—and why?

52. Are the Deanston stone-filled drains still anywhere used, and how formed?

53. State the effect of violent rainfalls on drained and undrained lands respectively?

54. Mention other rude materials used for drains besides stones?

55. What are, however, the best and cheapest, as well as most perfect, and their cost?

56. By whom has the laying flat of the surface after draining been recommended?

57. Is this injunction generally followed or disregarded, and what may be the consequences?

58. How long after draining is subsoiling generally resorted to?

59. What is the intention of the subsoil plough?

60. How is it worked, and why?

61. May the drains be farther apart where subsoiling is intended? Does Mr. Mechi's farm illustrate this?

62. What are Mr. S. Hutchinson's recommendations for subsoiling with four horses?

63. What, then, have we gained by draining and subsoiling?

64. How does the Moorland-pan, or pavement, originate?

65. Is drainage, then, required to prevent reclaimed tracts from relapsing into barrenness, and why?

66. Is it possible for lands to be over-drained?

67. How does the withdrawal of water affect pasture-land, and how is this retrievable?

68. What occasions the difference betwixt deep garden culture and ordinary tillage?

69. Mention a recent instance of deep farming?

70. How far is the British farmer still from having reached the limits of increased produce, as compared with more favoured lands?

71. What is the practice of the Flemings in regard to deepening their culture?

72. Give an instance of fertility in the intermixture of common ingredients, which, taken apart, are each of them barren?

73. What instance is cited by Bakewell of extraordinary natural fertility from intermixture of soils?

74. What pecuniary results were produced thereby, according to the evidence of Mr. Smith, of Deanston?

75. What was the nature of the process termed winter fallow, by Mr. Murray, of Polmaise?

76. What effect has manure, placed in a deep furrow, on the roots of plants?

77. What was the curious observation of Lord Kaimes respecting the enrichment of churchyards?

78. But what benefit must also proceed from the atmospheric action being deepened in the soil?

79. Mention several objections to drainage, and their answers?

80. How do the ordinary operations of agriculture tend to wall down unexhausted depths of fertile soil, and cut them off from the active stratum?

81. Do plants naturally send down their roots to a depth exceeding the nine inches in cultivation?

82. Mention facts regarding the fibres of the wheat plant?

83. What are the requirements of the plough for production of the best furrow slice?

84. In what county is the old wooden plough still in use?

85. What agricultural implements were declared the best at the competition at Windsor in 1851?

86. How are English iron ploughs regulated?

87. What superior element does the use of the swing plough call forth?

88. State generally the succession of crops in an improved six-shift course of husbandry?

89. What are the operations requisite in the first course?

90. What in the second?

91. What in the third?

92. What in the fourth?

93. What in the fifth?

94. What in the sixth?

LECTURES ON AGRICULTURE.

DIVISION III.

VITAL FUNCTIONS OF PLANTS.

§ 1. Defence of Normal Tuition. 2. Entomology. 3. Conjugation of Cells. 4. Hybridization—*ex. gr.* Dale's Hybrid Turnip. 5. Germination. 6. Moisture. 7. Temperature. 8. Access of Oxygen. 9. Darkness. 10. Properties and Appearances of Seeds—*ex. gr.* 30 White and 20 Red varieties of Seed Wheat described. 11. Proposal to model on this plan means of communicating a knowledge of Seeds. 12. Diseases of Seeds, with Remedies. 13. Process of Development in Germinating. 14. Times of Brairding, under conditions of. 15. Depth in Soil. 16. Supply of Oxygen. 17. Actinism. 18. Arrangement of Oil, Starch, and Gluten in Seeds. 19. Vital Action of the Chit and Glume. 20. Chemical Conversions. 21. Catalysis. 22. Directions of Radicle and Plumule. 23. Completion of the Plant.

§ 1. In our last lecture I applied myself entirely to the development of a regular course of agricultural labour connected with the manipulation of the soil. I have now to direct your attention to certain scientific considerations connected with the life of the plant; for scientific farming is defined by the agricultural chemist to be the ascertaining—of what substances the plants you wish to raise are made, which of these substances are wanting in your land, and what manures will supply them. As we attempted to show in a former lecture, scientific farming comprehends a great deal more than this; and agricultural chemistry, altogether, is only a part, although an important one, of our great and extended system of scientific knowledge as applicable to agriculture. I say applicable, rather than applied, because, to my sorrow, I perceive the Normal system I am seeking to establish to be heavily discouraged by the agricultural authorities, whose mistaken aim it is to enhance the profits of the great farmer and the large capitalist through the supposed resources of agricultural alchemy, regardless of the more patriotic purpose of diffusing a general knowledge of scientific truths and principles amongst the great body of the population. It is a serious discouragement to me to stand alone in a work like this. But it is not that only which depresses me. It is the retrograde spirit manifested in a recent report to the Poor Law Board in relation to the introduction of agricultural teaching into common schools, as a branch of practical education. Infatuated with the delusion that no great or valuable principles can ever be thus communicated, it declines to countenance the Normal system generally; but strange to say, admits its adaptation in destitute places. Agricultural chemistry lectures, although but a branch of our subject, form one of leading importance; and although I may observe that it is not for us to enquire out the truths of that and other eight or ten sciences applied in agriculture (having abundance of scientific testimony which we can accept), still, if there be a science in the whole curriculum worth spending upon it the time so valuable to those who are pressing forward to practical results, it is agricultural chemistry—the alphabet of scientific agriculture. With this brief defence of a system of practical agriculture, suited to the wants of every district in this country, where there exists industrial ignorance and its concomitants—pauperism, vice, and crime—

§ 2. I proceed to address myself to the immediate theme of this discourse, which I informed you should relate to "the life of the plant;" although I do not propose to get over more than the preliminary stage of its existence in the present lecture—attention to the nature and conditions of brairding appearing to me of paramount importance.

§ 3. The agricultural chemist in his analytical researches, too frequently forgets that it is not with inert matter but with vital organisms that the cultivator has to do. A plant is a living creature; and its vitality has necessarily so intimate a relation to productive science, that despite the dictum of a high authority, we venture to regard its conditions of life and development as of the highest importance to the farmer.

§ 4. Into those deep and perplexing questions of embryology on which there has of late been more discussion than on any other given point of vegetable physiology—it is unnecessary for me to enter, and it would be contrary to the educational practice for which I firmly contend, in all its efficacy, to do more than accept the comprehensive result of the thousand and one theories propounded on that subject, which, in regard to phanerogamic or flowering plants, is just that two cells, with different contents—the one the pollen grain, with its granular fovilla (a semi-fluid matter said to be seen to move under the microscope, like the minute living creatures known as infusoria)—the other the ovale, filled with mucilaginous or gummy fluid—being brought into connection—commence the embryo, which is a cellular body, or germinal vesicle. It is worthy of remark, that at a Botanical Society's meeting, which I attended as a Fellow, since the composition of this lecture, opinions intimating a belief that this conjugation of cells is the mode of propagation established throughout the whole vegetable kingdom from its highest organisms to its lowest, were strongly thrown out both by Professor Balfour and Mr. Wyville Thomson. Practically, this minute fact is of some importance. The pollen of one species being employed to fertilize the ovules of another; plants are produced of a character intermediate to the two parents. This is called Hybridization. For instance, in the cultivation of the turnip, instead of the green-top Swede, which is somewhat difficult of growth, or the white globe, which, from its small size, is less valuable, Mr. Robert Dale, an intelligent farmer at Libberton Westmains, in 1822-3, raised a mule or hybrid between these plants, with rougher leaves of more vivid green, and besides this strong and luxuriant characteristic foliage, with larger sized roots having the lightish yellow colour, the light green top, small neck and tap root of their parent Swede. This turnip is known as Dales' Hybrid. It resulted from repeated experiments in hybridization; and the advantage of the cross with the light white globe is, that, compared with any of the common yellow sorts, it is found to arrive sooner at maturity, and, consequently, may be sown at a later period of the season.

§ 5. The first vital act in which we find the plant engaged is that of germination. This is the first motion of the vegetating principle. The embryo in the seed, by this act or operation, bursts its envelopes and becomes a plant. Moisture, temperature, the access of air, or at least of oxygen, and to some extent darkness, are necessary to germination. But, in the first place, the seed itself must be mature and perfect. On this point there should be no delusion suffered by the practical man, who, too frequently, to save three-pence upon the pound of his seed, or such a mere bagatelle as half-a-crown on the acre, is tempted to purchase an inferior article, when he had better have paid a double price for genuine seed. To such a pitch have the frauds in the seed trade been carried—principally in England—on which country Scotland is also largely dependant for its supplies, as the climate and situation are more favourable for seed farms—that at this moment the papers teem with suggestions for detecting the unprincipled adulterations palmed off upon the agriculturists. It is not long ago since a copy of the *Morning Post* newspaper was addressed to me, giving circulation to an earnest article from the leading English agricultural paper, in which the difficulty of bringing these adulterations to any such analytical tests as the *Lancet* lately brought the impositions of certain grocers, apothecaries, and other tradesmen is pointed out, as well as the impossibility of expecting that every cultivator could mature his own seed, that being a business by itself, and one not always attended with certain profit. Turnip seed, for instance, to attain perfection, for the plant is biennial, infers transplanting, and besides the labour, an occupation of the place of two entire crops in the ground. To avoid this, and ensure anything like profit, the seed grower therefore will generally raise his seed from bulbs forming a stubble crop, sown in the latter portion of one year and matured, by transplantation, in the course of next. But for this the seed suffers both in quantity and quality. Unripe seeds seldom germinate, their parts not having attained the conditions necessary for forming the chemical combinations on which that process depends. And it appears that in addition to the mixture of ripe and unripe seeds sold to farmers by the cheap seed houses, in the case of the grasses and other small seeds, mixtures of wild seeds are largely introduced amongst those of true cultivation. Every matured seed will germinate. It does not depend upon the size. That which is blown off in the process of cleaning, as small dust, being found to spring as readily as the larger sort which remains behind; and in Ireland, where the seedsmen have greatly to depend on parcels of grass seed saved by the poor and ignorant peasantry, I find the able agricultural journals keenly remonstrating against the unripe condition of nine out of every ten lots. Some seeds are also impaired in their vitality by being kept any length of time. The germination of the common radish, pea, &c., Adanson, the great experimentalist on the vitality of seeds, has stated to commence in the very seed-vessel; although if protected from external influence, most seeds will certainly retain their vitality for a long, in some instances an incredible length of years.

Having selected, prepared, and sown the seed, it is time to dispose of the germinating process itself, which we stated to depend on certain conditions, moisture, temperature, the action of oxygen, and the exclusion of light.

§ 6. There must be moisture. Seeds, as we have seen, may be kept from germinating if perfectly dry. Hence the value of spring showers and of the wet seasons of all countries. The gardener, if rain fails him, resorts to artificial watering; and the old agricultural system of the ancient world was exclusively one of irrigation. The canals that traversed Mesopotamia astound the traveller of the present day by the extent and multiplicity of their remains; the early cultivation of Egypt, and the very enumeration of the rivers that environed Paradise, prove that moisture was always regarded as the first requisite of vegetation. There are many beautiful illustrations of this vegetative fructification strewn throughout the Scriptures, and none of them more felicitous than in that lofty poem, the 55th of Isaiah, "Ho, every one that thirsteth come ye to the waters," where at verse 10 it is said, "For as the rain cometh down and the snow from Heaven and returneth not thither, but watereth the earth and maketh it bring forth and bud that it may give seed to the sower and bread to the eater, so shall my word be that goeth out of my mouth." Now, the just application of water is a delicate process! Rain is always partial, and for the most part appropriate; but irrigation may be underdone or it may be overdone. If the supply of moisture be defective, the seed perishes from that cause. If superfluous moisture be supplied, it rots. One of those judgments of God evoking the terrible call to repentance raised by the prophet Joel describes this calamity, and also the practice to which I must shortly refer, of covering in the seed from the light. "The seed," he exclaims, "is rotten under their clods, the garners are laid desolate, the barns are broken down, for the corn is withered." Peas half immersed in a piece of wet sponge germinated, according to an experiment of Du Hamel, as if they had been placed in soil; but when totally immersed in water they did not germinate—they rotted—although the seeds of aquatic plants must necessarily germinate on submersion, and peas under certain conditions might do the same. Moisture, in the first instance, swells and softens the seed; in the next, it places the nutritive matters in the soil in a state of solution, whereby they produce certain changes in the seed. In this process of germination, therefore, plants frequently absorb a large amount of water. Thus a French bean, weighing 544 milligrams, was found by Decandolle to absorb 756 of water. The swelling which takes place in seeds by this absorption enables even kernels to burst their stony envelopes.

§ 7. The temperature at which seeds germinate is placed by Balfour at from 60° to 80° Fh. To their incapability of germinating below the freezing point, or, indeed, below 32° Fh. (as somewhere stated by London) we owe the dormancy of winter. Adanson found seeds to germinate in an ordinary degree of heat in twelve hours, and by exposure to a greater heat in three. Thus it is that seeds transported from a moderate to a tropical climate, as from Paris to Senegal, are accelerated by from one to three days in germination; whilst those taken from a warmer to a colder climate have the period retarded, as in the case of exotics raised under conservatories. The highest prolonged temperature which the cereal grains will bear in water, without destroying their vitality, has been fixed by Edwards and Cotin at 95° Fh., and 118° in earth and sand. Wheat, oats, and barley thrive in any country where the mean temperature exceeds 65° Fh.

§ 8. John Ray discovered that lettuce seeds failed to germinate in the exhausted receiver of an air-pump, but did so on the readmission of air. The access of air is therefore essential to germination. Seeds buried so deeply in the soil as to be excluded from air, as we have seen, do not spring up until brought near the surface.

Experiments performed by Petri also show that plants may be too near the surface as well as too far from it: thus seven-eighths of a certain number of plants sown half an inch deep came up in 11 days; the whole of a like number one inch deep came up in 12; seven-eighths two inches deep in 18; six-eighths three inches deep in 20; four-eighths four inches deep in 21; three-eighths five inches deep in 22; and one-eighth six inches deep in 23. Shallow sowing is thus found to be best, its germination most rapid, and, indeed, it is generally held that the depth at which seeds should be covered in should not exceed from one-half to two inches, according to soil and circumstances. The seeds themselves manifest considerable diversity of period in germinating. The grasses germinate most rapidly. Thus, in Adanson's table, wheat and millet seed are assigned only one day, but barley seven. Cruciferous plants, turnip, mustard, &c., are the next in promptitude. Adanson assigns spinach and mustard seven days, lettuce and aniseed four, radish and beetroot six. The leguminous plants perhaps, as early beans, take three days. The labiate or leafy plants, take longer, as the cabbage, ten days; and the umbelliferæ longer still, for parsley requires from 40 to 50 to come up. Humboldt seems to have been the first who instituted steeping in chemical solutions for accelerating the germination of seed. Cress seed treated by him with steeping in water impregnated with oxy-muriatic acid—the bleaching gas or substance termed chlorine by Sir Humphrey Davy—germinated in three hours in place of their usual period of 32. I know a Berwickshire farmer who resorts to the rather unusual practice of pickling his turnip seed, which, although attended with a difficulty in the sowing and not easily dried, he regards as a means of preventing the ravages of the fly from the rapidity of germination hurrying the plant over that tender stage of existence where it is at the mercy of the insect. It is well known that the steeping of seeds has been pushed theoretically so ar as to suggest the possibility of starting the plant, and even perfecting its productiveness without manure. But it does not appear that the laws which regulate ordinary vegetation act upon the sprouting germ; for whereas plants derive their green colour from their assimilation of carbonic acid from the atmosphere, it seems to be oxygen alone that the germ seeks from the admission of air into its dark abode beneath the soil—germination being, in fact, a branch of that slow combustion or eremaucausis, which I mentioned in my first lecture, and the supply of oxygen being as essential to it as to a candle burning; whereas, as Johnston in his little catechism beautifully shows, you may very simply prove by putting a few green leaves under a large glassful of pure spring water, and setting them out in the sunshine, that the leaves of plants give off oxygen gas, for small bubbles of it will be seen to arise from the leaves and collect in the upper part of the glass. The leaf takes up the carbon and sets free the oxygen in the water. It is not the case, however, that the oxygen, although its presence is necessary to germination, is taken up by the incipient plant. Only it is a striking fact that while such is the case it was proved by Achard that no seed will germinate in nitrogen, hydrogen, or even carbonic acid gas—oxygen being the only constituent of the atmospheric air which is absolutely necessary.

§ 9. With regard to *darkness* in connection with germination, it is the principle on which the farming practice of harrowing or raking in the seed is founded; a practice, as we have seen, recognised in scripture, and traceable to the earliest times. To take a familiar instance, the growth of the hyacinth is generally commenced in a dark closet. Of certain auricula seeds covered by a transparent bell jar, others by jars of ground glass, and others by a jar shrouded in black cloth, Boitard found the last germinate most rapidly; and Mr. Hunt's experients with light have determined that whilst the rays nearest the yellow (which is the natural colour of light), most impede germination, and the red, being heat-giving rays, are rather favourable to it, provided there be abundance of moisture; the blue rays, being those concerned in chemical action or *actinism*, cause the most rapid acceleration of the process. Thus the hyacinth will grow best in a blue glass. And Mr. Hunt suggests a pale green made with oxide of copper, as adopted in glazing the palm house at Kew, as best adapted for conservatories, because the scorching rays are excluded and the others are admitted, for green is a compound of the yellow or luminous, and the blue or chemical—and you, perhaps, know that Newton's seven prismatic rays of light have been reduced by modern science to these three.

§ 10. So essential seems it to me, in practical agriculture, carefully to study and ascertain the properties and appearances of seed, and so little has been recorded on this subject, which is one of those treasured retentively by the practical man, and reserved exclusively to be purchased by slow experience, that I would gladly indulge in some detail regarding this matter. But it must suffice if I take for example the characteristics and varieties of seed wheat to illustrate the manner and extent to which this important but neglected point of agricultural instruction may be cultivated. In Lawson's Synopsis of the Cultivated Products of Scotland, I find nearly one hundred and eighty, that is to say, 179 distinct varieties of cultivated wheat and spelt; an even in Vilmorin's Catalogue Methodique des Froments (1850), 53 sectional groups, composed, indeed, of synonyms for the varieties to some extent, but also comprising often from 6 to 8 distinct wheats introduced into cultivation. The consultation of Lawson's Agricultural Manual, of which the Synopsis is a new edition, is perhaps necessary to afford a good choice of seed—for there the results of production, and history of the introduction of each item in the extensive series are stated, and in no other work of which I am aware, as well as that distinguishing mark given for each quality of seed grain which the Corn Market or Exchange has long been supposed alone capable of imparting, by long experience, in handling and examining grains and seeds, to the farmer or seedsman. Of seven kinds of cultivated wheat, three only are commonly grown in this country—the common, the turgid, and the hard wheat; one of the other four being adapted solely for the torrid zone, and the three others, including spelt, having adhesive chaff. The common wheat, *Triticum Sativum*, is distinguished into white and red varieties—or exhibiting three different types if regarded rather in the form of the ear than of the grain, as represented by Piper's thick set, Chiddam, and Bellvue Talavera wheats respectively. A few prominent examples will evince the differences subsisting in the aspect of these grains. Thus, of the white varieties:—

Archer's Prolific, a very beautiful sample, has a grain of medium size, thin skinned.

Barbary thick chaffed wheat again is almost like Triticum Durum or hard wheat, its grain is large, oblong, lightish yellow coloured, and somewhat flinty.

Baxter's has a grain round and deeply furrowed.

Brown strawed wheat, a fair sample of medium size.

Cape Bearded, a rather superior sample of large elongated and in general well filled whitish-coloured grains.

Caucasian Bearded Yellow, a good heavy sample, has large oblong yellowish-coloured rather thick-skinned grains.

Ten-rowed Chevalier, a superior heavy sample, has on the other hand thin skinned grain.

Chiddam, grain more slightly elongated, rather thinner in skin, more transparent and flinty than the famous Uxbridge wheat.

Tall Cluster, grain rather small, short, of a dullish white colour, but forming a good bearing sample.

Dantzic, (as grown in this country,) a very small elongated grain of a beautiful white colour.

Hunter's, and its improved form known as Hopetoun, has rather large elongated grain, tapering very slightly towards the extremity, plump, and of a uniform dull white, or rather what we might call whitey-brown throughout.

Of Colonel Le Couteur's Jersey wheats, the compact kind has a grain of ordinary size, oblong, rather thick skinned, forming a good sample; the round kind yields a thicker skinned inferior sample; his Jersey Dantzic, a medium sample of oblong transparent light coloured grain; and his No. 5, ditto thickish skinned grains, forming rather an inferior sample.

The Pearl, Red Chaff, Red Strawed, White, and Saughton Yellow, are perhaps the kinds most familiar in the Scottish wheatland districts: the first roundish and white, like the old Uxbridge; the second a superior sample of white thin-skinned grain; the third a fair sample plump and round.

The common bearded spring wheat, at one time the most extensively cultivated wheat in France, has a small grain.

The common white beardless spring wheat, a grain short, plump, and of a dull yellow or brown.

Talavera, which some years since, was a good deal cultivated in the Lothians and other wheat districts of Scotland, although an opinion now obtains of its being too tender to withstand the ungenial weather of their spring time, has a large semi-whitish transparent grain.

Talavera Bellvue, already mentioned; the earliest bearded variety in spring culture in this country, has a grain unusually large, oblong, thin skinned, and very white, forming a superior sample.

Uxbridge, a beautiful sample, much esteemed by the London millers, who prefer it to any other; a rather small, short, plump grain, and of a very white colour.

Velvet, or woolly eared wheat, against which though in extensive cultivation our farmers entertain an objection I had better mention, namely, the retention of damp by its woolly chaff, which you know would impart a tendency to sprout, and injure the sample, has a well formed middling-sized grain, of a semi-transparent whitish colour. It is much esteemed by those most practical of critics the London millers; for why? it yields little bran and much fine white flour.

The Victoria variety, found by Humboldt in the Caraccas, has a long reddish coloured slightly cornered flinty grain.

Whittington, though a wheat for thin soils, has a large, oblong, thin-skinned grain, and forms a very superior sample. These are the white wheats only—of the reds

Belgian, a fine sample, has a grain of medium size and bright red colour.

Blood Red, also a medium-sized grain, of dark yellowish or copper-colour, especially at the thickest end.

Burwell: large, longish shaped, deep reddish grains—a fair sample.

Cambridge Brown: deep brown large oblong grain, tapering towards a point—a good sample.

Caucasian: elongate, semi-transparent, rather above the medium size, hard and flinty.

Clover Red, a good sample, large, oblong, lightish red coloured.

Fern, better known as April wheat, has a grain elongated, of a bright red, and rather flinty.

Golden Drop, grain about the size of Blood Red, but more uniform and lighter in colour.

Golden Red, best known, perhaps, as Essex Red, grain longer than Blood Red, not so round and compact, and more obtusely angled on the sides.

Old Red or Common has an elongated grain of a dull reddish colour.

Early Spring, one of medium size and semi-transparent dull red.

Victoria Red Spring, a fair sample, also of medium size.

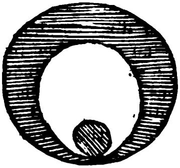
§ 11. These distinctive appearances presented by seed grain must be taken simply to show what could be done in the way of imparting valuable practical knowledge even in a school. Let samples of the most approved varieties of cultivated seeds be collected by public instructors, and their pupils familiarised in some such way as this with their characteristics, and I will answer for it that even the Agricultural Society will come to discover the value of the Normal scheme of agricultural education, whence the idea of so simple and attainable but instructive a museum emanates.

§ 12. Having pointed out the way to a vast region of information to be imparted to rustic pupils, I cannot dwell upon this branch of the subject; but it is impossible to quit it without directing your attention to the diseases, especially of a fungoid character, incident to seeds, of which it were ruinous to the cultivator to continue ignorant. With regard to the cereal fungi I shall, however, only pause to notice those attacking the grain or seed, or otherwise getting attached to, and apt to be propagated along with it. Bunt for example, and smut, of the multitude of whose prolific sporules or fine seeds no conception can be formed—for when the grain is threshed, the bunted seeds ruptured, and the sporules escaping, infection spreads throughout the corn heap. The greasy, oily, cloud of sporules adheres to the skin of sound grains, and the disease is even propagated by rubbing sound wheat against that infected by the fungus. Chemistry alone can cure this by an alkali, which will convert the oily or greasy matter into soap, and this is the basis of all effectual dressing or pickling for seed corn. Lime, which we set down in our introductory lecture as an alkaline earth, potash, ammoniacal substances, such as the excrements of animals, lime, sulphate of copper, arsenic, and even things not possessing alkaline qualities are thus employed. Smut is less easily got rid of than bunt, which floats on the surface when the grain is washed with water; whilst smut, because of the scattering of the spores at an early season, becomes extensively diffused. But although judicious dressing will always check bunt to a considerable degree, it is still considered bad farming to have much of it on any farm, because the real safeguard is the perfect purity and cleanliness of the seeds. It prevails more amongst spring than autumn sown wheats, and when grown up along with the wheat, ground with it and intermixed with the flour, it is excessively disagreeable, and probably injurious to health. No corn plant of this country save wheat is, however, affected with bunt. Another *uredo*, or rust, is found to destroy lucerne in Algeria; and eight or nine other kinds of vegetables are known to suffer in their parts of prolification from different uredines—especially the grasses, where it propagates within the sheaths. It is a common prejudice that the Barberry-tree causes fungoid disease in corn—the leaves of this beautiful shrub having a common fungus, the *aecidium*, which at a casual glance much resembles rust. The disease called ear cockle, pepper-corn, or purples, attacking the farinaceous portion of the grain is produced by a parasite or living creature, by whose blighting influence the whole ear assumes the appearance of black pepper-corns. Divide one of these in two, you will find it filled with a white cottony mass. *That* is a dense body of living eel-shaped animalculæ, estimated by Bauer to amount to 50,000 in one grain—the *vibrio tritici*—so called from their being found to wriggle about with great vivacity after some hours immersion in water, and even after being for years in the pepper-corn. Now, of course, unless a future crop of pepper-corns is desired you are not to commit this live stock to mother earth, to propagate along with your seed. For the grains containing the vibriones when sown with the seed burst in the spring, the animalculæ are set at liberty, and entomologists assert that the eels sometimes reach a quarter of an inch in length, and produce whole strings of eggs. These being laid in water are supposed to be drawn up by the roots of a plant, as bunt and smut spores are, into the interior of its stem. The Ergot, which attacks wheat and rye is not, however, a fungus, but one of the most singular monstrosities met with in nature. It is accompanied by a certain fungus. But the Ergot itself is a monstrous state of the seed, one part of the embryo of which is made to protrude in a curve resembling a cockspur—whence our spurred wheat and the French name "Ergot." It is black, spungy and oily, common in rye, and more common than is generally suspected in wheat and grasses, especially in *lolium perenne, lolium arvense* (perennial and common rye grass), *festuca pratensis* (meadow fescue grass), *phleum pratense* (Timothy grass), *dactylis glomerata* (rough cocksfoot). The medicinal effects of Ergot in small doses are important; but ground up with flour it has been found to produce the frightful gangrenous diseases prevalent as epidemics amongst the poor in certain districts in France. Low meadows, where the cattle were once certain to be taken ill, on being drained have been searched in vain for ergot in the grasses. But a careful examination of the grasses growing near hedges will disclose to the inquirer, in autumn, more ergot than he may imagine. Pigs running about green lanes thus become diseased from it. The small and shrivelled grains, from which every farmer sustains such constant loss by their large admixture in the sample, proceed from still another cause—a parasitic fly of singularly beautiful formation, —the wheat midge or *cecidomyia tritici*—often seen in the warmth of June, from 7 till 9 in the evening, swarming amongst the blossoming corn. A full third of the wheat in the Carse of Gowrie annually falls a prey to this tiny pest. These evils, and similar ones incident to the turnip seed, &c., are all to be either evaded by careful selection, cleansing, or pickling of the seed; and in the last instance, as urged by Mr. George Bell, a correspondent of the *Scot. Agric. Journal*, in the Carse of Gowrie, perhaps by accelerating artificially or naturally the blossoming period, and outwitting the midge altogether, which seems punctual to a day in its annual visitations—forward kinds of wheat, and possibly steeping the seeds being conducive to germination—may lead to the extirpation of this destructive pest, for when the plant gets over the blossoming stage before their appearance they cannot attack it, and are themselves devoured by ichneumons lodging in their bodies.

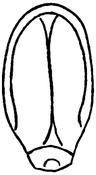
§ 13. The various conditions thus so essential to germination prove the great importance of the soil being completely drained, perfectly pulverised, and the seeds disposed at due and uniform depth, and dispersed at regular intervals. "Pulverised soil," says Professor Balfour, "when examined, is found to consist of small particles, having cavities in their interior, and separated from each other by interstistical spaces. In a very dry soil all these cavities are full of air; in a very wet undrained soil they are full of moisture; while in a perfectly drained soil the interstices are full of air, and the particles themselves are moist. The seed in such a soil is under the influence of heat, air, and moisture, and is excluded from light. Hence it is in very favourable circumstances for germination. Frost has an important effect in pulverising the soil by the expansion of the water contained in the particles when it is converted into ice. Snow, again, acts in giving a covering to the young plant, protecting it from intense frost, and sudden alterations of temperature, and by its slow melting allows the plant to accommodate itself to the mild atmosphere. Snow contains often much oxygen! If a field is not equally planted, the seeds will sink to different depths, and will spring up very irregularly. The seeds should be placed at a depth not greater than two inches!"

§ 14, 15, 16, & 17. The prolific mummy wheat—if we are to consider it not a hoax practised by roguish Arabs on credulous Europeans—thus is seen to rear its taper stalk and bearded head after a slumber of three thousand years in the tombs of Egyptian princes. Loudon mentions the less apocryphal case of a field ploughed up near Dunkeld, after forty years' rest, which, without sowing, yielded a considerable blade of black oats, the plough having brought to the surface seeds too deeply lodged for vegetation. And Balfour gives other instances, attributing to this cause the common sight of a crop of white clover and other plants that had not previously been seen in the locality springing up, as mentioned in our last lecture, on turning up the ground for the first time after thorough drainage and subsoiling. Thus, also, after the great fire of London, plants sprung up whose seeds had long lain dormant. Mr. Vernon Harcourt records a remarkable case with regard to turnip-seeds which had lain in a dormant state for seven or eight years, in consequence of having been carried to a great depth in the soil. Seeds from under six feet of peat moss have germinated in Stirlingshire; and Mr. Kemp mentions the germination of certain farinaceous seeds from the bottom of a sand-pit 25 feet deep, which, he concludes, must have been deposited there for 2,000 years. Still, it is a practical advantage that seeds for cultivation should invariably be fresh as well as good. Oily seeds, in particular, quickly lose their vitality, their power of absorbing oxygen inducing immediate chemical changes. The circumstances referred to in which seeds were protected from the influences of growth, are found difficult of imitation, for we sometimes wish to imitate this, as, for example, in sending them on a long voyage to foreign countries or the colonies—the most approved plan being considered simply to send them dry, in paper, cool and exposed to ventilation, suspended in a coarse bag in a cabin, although this will not always do; and dry earth and sand, powdered charcoal, tin covers, hermetrically sealed bottles of carbonic acid gas (a preventative of germination), wax, and sugar, have all been resorted to—the latter, too, with most success in preventing sprouting and consequent debility in a three or four months voyage. Seeds fully ripened, hard and dry, have thus a vast advantage over those not fully ripened, apt to decay, and easily affected by moisture. Large seeds retain the germinating power longer than small ones—corn, pulse, and farinaceous seeds generally live for a long while if gathered ripe and kept dry; although seeds may be fit for food that are not fit for germination. Decandolle tried a direct experiment, whence he concluded that the duration of vitality was frequently in an inverse ratio to the rapidity of germination. Of seeds 15 years old he took 868 species, sowed them at the same time, under similar circumstances, in the same garden, and found that only 17 out of the whole 368 would germinate! He found that woody species preserved the germinating power longest, for, 5 out of 10, or 50 per cent. of apple and other fruit tree seeds came up. Of the Leguminosæ, or pea plants, 9 out of 45 species, or 20 per cent. appeared. The perennials lost their vitality sooner than the annuals. The biennials, or plants requiring two years to come to maturity, preserved their vital power the shortest time of all.

§ 18. The analysis, or rather the superficial examination of any ordinary seed, shows it to be composed of three portions, externally the oil contained in glutinous hexagonal cells, but chiefly the starch constituting the bulk of the seed, and finally the glume, chit or germ chiefly composed of gluten, and generally situated at one end, as in Indian corn, wheat and barley; although in

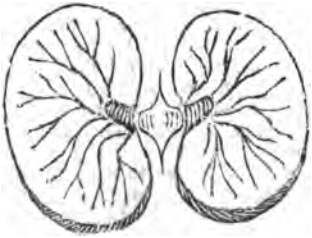


INDIAN CORN.



WHEAT.

BARLEY.



GARDEN BEAN.

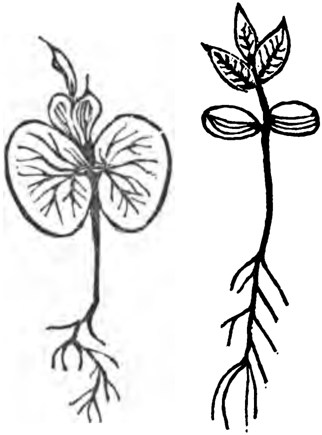
the garden bean plume, it will be seen, is a small white point projecting from between the lobes, these lobes by the way are the cotyledons. In wheat there is but one colytedon, that plant is therefore termed by vegetable physiologist, monocolytedonous ; the garden bean, which has two, dicotyledonous as in the greater number of instances in nuture; some plants, however, have more, and are polycotyledonous.

§ 19. The seed commences the act of generation by the prolongation of its radicle. That is to say, when swollen by absorption of moisture, it undergoes certain chemical changes by which its contents are rendered fit for the nourishment of the embryo.

§ 20. One of the most remarkable of these changes being the conversion of starch into dixtrine and grape sugar by oxidation, converting an insoluble into a soluble substance, and developing a substance alluded to in our first lecture, the nitrogenous compound diastase, so effective in converting starch into dixtrine and sugar, referred by the German chemists to their new and wonderful doctrine of catalysis.

§ 21. The same process takes place in the malting of barley, which is just incipient germination, where starch is converted into sugar, oxygen is obsorbed, carbonic acid given off and heat if not low combustion produced. Moisture being now imbibed by the pampered embryo, it continues to increase till it fills the cavity of the seed and bursts through the softened integuments—the cotyledons (which, as in the bean, are fleshy, and contain as we have seen, in all seeds, starch, aud oil) supplying the nourishment.

§ 22. The radicle begins to push its extremity towards the earth, but the plumule, meaning to emerge upwards or in an opposite direction, soon separates from it and appears above ground, accompanied by the cotyledons, if there are any, which frequently appear upon the surface and act for a time in the capacity of leaves, until the first real leaf protrudes from between them and expands in the open air, attended, if such be the character of the plant, with the rudimentary development of the stem :—



§ 23. Thus the plant becomes complete. Let the seed be deposited as it may, the radicle invariably descends and fixes itself in the earth, whilst the plumelet mounts into the air. For this inveterate result of germination, and the strange instinct by which the two vegetative powers of the young radicle and plumule take opposite directions, it has puzzled philosophers to account, although it has been the subject of the most ingenious experiment, Mr. Knight having fixed germinating plants on revolving vertical and horizontal wheels to try how far gravitation might be the cause; whilst Dutrochet, as Sir Humphrey Davy tells us, found that when moist earth was placed above plants germinating in a box, and access given through holes below to the dry air—the former had still no attraction for the roots, and the latter none for the leaves, which respectively persisted in entering the inappropriate medium in which they perished.

Thus have I sought to dwell on the subject of germination, well assured that in getting the productions of the farm over this first stage of life, the work of the agriculturist is more than half done; and that, consequently, one of the main points of scientific instruction must be to teach the mode of attending to this most critical of all the natural processes through which the plant has to pass. In another lecture I shall complete the general view of the vital and organic functions of plants in connection with their proper culture.

INCIDENTAL QUESTIONS.

1. How is scientific farming defined by the agricultural chemist?
2. Does it embrace more?
3. How would a Normal school system of agricultural teaching tend to diffuse scientific knowledge and amongst what classes?
4. Should agricultural chemistry occupy a prominent place and why so?
5. What stage in the life of the plant is of primary importance?
6. Why should the vitality of plants be strictly kept in view in dealing with them?
7. Can you explain in a few words the embryology of flowering plants?
8. What is the conjugation of cells?
9. How does hybridization ensue?
10. Give an instance of well-known agricultural produce?

11. When was Dale's hybrid produced? Was it the result of one or of many experiments? And what are the advantages of the cross with the light white globe over any of the common yellow sorts?

12. What is the first vital act in which the plant becomes engaged?

13. In what condition must the seed be, preparatory to germination?

14. Are frauds common in the seed trade?

15. Where are the principal seed farms situated?

16. Mention a biennial plant hurried on to seed by autumn culture and the defective results?

17. Are mixtures of ripe and unripe seeds ever vended?

18. What other disadvantageous mixtures abound?

19. Will seeds germinate irrespective of sise? and on what conditions?

20. Are seedsmen in any case dependant on seeds saved by ignorant and needy persons? and what is the consequence?

21. Do seeds become impaired in vitality by being long kept?

22. At how early a stage has Adanson, for instance, stated the germination of the common pea, radish, &c. to commence?

23. How, and in what manner must seeds therefore be protected to preserve their vitality?

24. On what conditions does germination depend?

25. Explain, as respects moisture, the value of spring showers, &c., and why substitutes are resorted to during drought?

26. Mention a country covered with vast remains of early systems of irrigation?

27. Quote Scripture texts relating to vegetative fructification from watering of the earth?

28. What would be the effect, however, of superfluous moisture? Does Scripture also corroborate this?

29. State Du Hamel's experiments of half and total immersion of peas, and the results on their germination?

30. Do any plants germinate on submersion?

31. State the process by which moisture contributes to germination?

32. Do seeds in germinating absorb much water? Specify example of nearly a third more than its own weight?

33. To what powerful result does the swelling, produced by this excessive absorption, conduce?

34. At what temperature, according to Professor Balfour, do seeds germinate?

35. To what, therefore, may we ascribe their dormancy in winter?

36. How did Adanson find heat affect germination?

37. In what instance is this inverted and germination retarded.

38. What prolonged heat will cereals endure according to Edwards and Cotin? and at what range of the thermometer do wheat, oats, and barley thrive?

39. How did John Ray prove the access of air to be requisite to germination?

40. What takes place with regard to seeds deeply buried in the soil until brought up near the surface?

41. What do Petri's experiments on the contrary show respecting plants too near the surface?

42. Mention the relative proportions that came up, sown at different depths, and their times of springing?

43. State then the advantages of shallow sowing; and what reasonable depth would be best to adopt in the generality of instances?

44. What class of seeds germinate most rapidly?

45. What difference does Adanson ascribe to barley, as compared with wheat, in rapidity of germination?

46. What class of seeds springs next early?—Give instances.

47. How long do leguminous seeds take?

48. How long those of labiate plants?

49. How long umbelliferous—parsley for example?

50. Who first tried steeping of seeds in chemical solutions?

51. How did Humboldt treat cress seed?

52. Is there any pickling practice known in Berwickshire relative to turnip seed?

53. What hope is there of stimulation in the germ? Do the laws of ordinary vegetation apply?

54. Whence do plants, for instance, derive their green colour?

55. And what gas alone does the germ imbibe underground?

56. What in fact is germination? And why is a supply of oxygen needful?

57. How does Professor Johnston suggest showing that green leaves give off oxygen?

58. What does the leaf take up in the water in liberating the oxygen?

59. What striking fact has Achard proved regarding the non-germination of seed in other gases?

60. What farming practice is founded on darkness being a condition of germination?

61. Name a familiar example of the occurrence of this condition?

62. State the results of Everhard's varied experiment with auricula seeds?

63. What have Mr. Hunt's experiments with light determined?

64. Has much attention been given, and is much and general attention required to the properties and characteristics of agricultural seeds?

65. How many distinct varieties of cultivated wheats are given in Lawson's synopsis?

66. How many groups in Vilmorin's Catalogue Methodique?

67. Is there any Manual for consultation in the choice of seed?

68. Of seven species of cultivated wheat, which three are commonly grown in this country? and why not the other four?

69. Which is the common wheat, and what its varieties and types?

70. Could you rehearse the properties of the thirty seed wheats most in vogue?

71. How does this show what is capable of being done in schools? and how could these important distinctions of seed grain be best illustrated there?

72. To what diseases are the cereals most incident?

73. Mention some common cereal fungi attacking the grain and propagating along with it?

74. What is the nature of bunt and smut?

75. How is bunt to be cured?

76. How smut?

77. Does any other *uredo* or rust save bunt attack wheat?

78. Do other kinds attack other grasses?

79. What superstition prevails regarding the *acidium* attacking the Barberry tree?

80. What is the disease called ear-cockle, peppercorn, or purples in wheat?

81. What remarkable appearances do the peppercorns present when cut open?

82. Is *ergot* in wheat and rye a fungus or monstrosity or sport?

83. Describe it?

84. What grasses does it also commonly affect?

85. What are the medicinal effects of *ergot?*

86. Are cattle and pigs ever affected by it and in what situations?

87. In what month does the wheat midge swarm?

88. Do you recollect its scientific name?

89. To what extent does the wheat sometimes differ?

90. What has Mr. George Bell (the reaping machine inventor) urged by way of overcoming this?

91. Show the importance of the soil being completely pulverised, in order to forward the process of development in germination?

92. How long may the mummy wheat have lain dormant if not a hoax?

93. How long the black oats near Dunkeld noticed by Loudon?

94. What is stated by Balfour respecting white or "indigenous" clover?

95. What remarkable revivification of dormant seeds occurred after the great fire of London?

96. How long does Mr. Vernon Harcourt say that turnip seeds had lain dormant?

97. Give examples of seeds germinating after lengthened confinement under peat moss and deep sand.

98. Is it then practically advantageous that seeds should be fresh and good?

99. How may seeds be forwarded on long voyages?

100. What advantage do seeds fully ripened and dried possess over those not so?

101. Do large seeds retain germinating power longer than small ones?

102. At what conclusion did Decandolle arrive regarding the duration of vitality and the rapidity of germination in seeds?

103. Mention the results of his experiments?

104. Of how many portions does the analysis of any ordinary seed show it to be composed?

105. Where is the oil situated; where the starch and where (generally) the glume or gluten?

106. What is it? and where are the cotyledons?

107. Why is wheat called monocotyledonous?

108. And what corresponding term is applied to the garden bean and most other instances in nature?

109. What are plants having more cotyledons called?

110. What is the first commencement of the act of germination in the seed?

111. What remarkable conversion ensues?

112. What is the name of the principle developed?

113. How does moisture now perform its office?

114. In what directions do radicle and plumule respectively begin to push?

115. Describe the process of completion of the plant?

LECTURES ON AGRICULTURE.

DIVISION IV.

AGENCIES AND PRODUCTS OF CULTIVATION.

§ 1. The Practical Inculcation of Agricultural Science by Normal Teaching and Excursions. 2. These Lectures as a Text Book. 3. Arrangement of the Homestead. 4. The Manufacture of Manure. 5. Fermentation of the Dungheap. 6. Importance of Farm-yard Manure. 7. Peculiar Management of Horse and Cattle Dung. 8. Straw. 9. Habit of the Animal as affecting the value of Manure. 10. Proportions of Inorganic Matter consumed and voided. 11. Guano. 12. Its importation. 13. Mode and Effects of Application to White and Green Crops. 14. Nitrogenised Principles of Animal Manure. 15. Green Manuring. 16. Comparative Test of the leading Specifics. 17. Mr. Lawes' Arrangement of Artificial Manures. 18. Results of various other Applications. 19. Proper Application of Manures in an ordinary Six-shift Rotation, with remarks. 20. Tanks and Liquid Manuring of Soiling Crops. 21. Ennumeration and Value of the Principal Artificial Agents of Commerce. 22. Phosphate of Lime. 23. Nitrate of Soda. 24. Sulphate of Soda. 25. Sulphate of Magnesia. 26. Sulphate of Ammonia. 27. Common Salt (Chloride of Sodium.) 28. Gypsum. 29. Balance of Oxygen and Carbonic Acid in the Vital Action of Plants. 30. Vegetable Mould. 31. Sources of Hydrogen and Nitrogen required by Plants, and vast extent of the latter in Cultivated Crops. 32. Hence the *rationale* of Fertilizing the Soil. 33. And three ultimate conclusions of Science regarding the Growth of Plants. 34. Exception to the Rules of Production in the Growth of Flax. 35. Identity of the Laws of Feeding Stock with those of Vegetable Culture. 36. Comparative Feeding Values or Equivalents and Prices of Agricultural Products in Feeding Stock.

§ 1. Having summarily rehearsed, in the course of the preceding lectures, the bearings of modern science and discovery upon the cultivation of the ground, with a view to expiscate the principles upon which the system of British husbandry might be explained as a branch of practical instruction, I cannot help urging that earnest attention is required to follow a course proverbially dry in its scientific details as Agricultural Science is known to be, and uninteresting as it may have appeared when separated from practical and particularly field illustrations. Normal instruction in agriculture, or the training of agricultural teachers in order that they may impart instruction in other quarters, is the primary object set before me as an element of general information. The inculcation of productive science, in favour of its adoption as a branch of practical education may yet be introduced into quarters now averse to the movement, and ignorant of the consequences it is distinctly calculated to produce in the moral, social, and economical prosperity of the people. It was my intention to have proposed premiums for the best account of the lectures delivered in this course, and for the best details of the operations pursued upon any farm within ten miles of the place of lecture, as illustrative of improved agriculture, betwixt Candlemas and the separation of the ordinary crops from the ground, to serve as a slight memorial of our brief agricultural course. It has always been my belief in turning my attention, however, to the subject of agricultural education, that in the proper organization of any class for that branch of study, it would be easy to arrange with one or more eminent neighbouring farmers, avowed improvers, liberal and generous in their views, to establish a set of visitations or excursions in illustration of the course, similar to a proposal of mine honoured, in 1848, with the approbation of the magistrates of Aberdeen, though outvoted by the Professors of Marischal College, in the last election to the Fordyce Chair of Agriculture; and similar to the excursions of the Botanical Classes of Edinburgh College.

§ 2. I take also the opportunity of stating that in consequence of the total want of a suitable Class Book, as explained in my first lecture, I have prepared my lectures themselves so as to constitute a Text Book of Agriculture, adapted for schools and lecture-rooms, embracing in its several divisions, calculated to be used either together or separately—1. Scientific Agriculture, and 2. Practical Agriculture; and including not only the full curriculum of the compound science itself, but all its most recent applications. We have already glanced at all the leading principles of agriculture. We have traced the elements that operate in nature, and have described the influences they exert on vegetation; we have treated of the manual labours of the husbandman in preparing the soil, and have even conducted the tender plant over the first critical stage of its existence on the path to fruition. It still remains to refer to THE AGENCIES AND RESULTS OF PRODUCTION both in regard to the vegetable and animal produce of the farm. And this I shall do as concisely as possible, since our time restricts us to but a cursory glance of a rather comprehensive topic.

§ 3. Practically, a farm is nothing else than a large manufactory of vegetable and animal produce. With regard to the former, or vegetable returns, in accordance with the laws of production, the farmer must parcel out the land into divisions, and crop these in the succession of the rotation he may have adopted from its suitableness to the nature and capabilities of his soil. With regard to the latter, it is important that the arrangements of the homestead where it is carried on should be fitted to yield all those facilities of mutual access from one part of them to another which are best calculated to save double carriages, such as might arise from the threshing-barn and machinery being too far off from the rick yard, the straw-barn from the cattle sheds, or the cattle courts from the manure heap; and at the same time should be so free from interruption to feeding animals as to ensure their perfect and undisturbed repose—the great secret of box or stall feeding being now well understood to consist in inducing the animal to satiate itself with food unmolested. When it is considered how far the operations on a farm proceed in a circle, inasmuch as certain parts of the vegetable produce, after being realised out of the soil, are subjected to the process of animal digestion, fertilised and returned to the soil, again to re-impart fertility to it in turn—the growing importance which begins to be attached to the subject of *Farm Steadings* will be readily appreciated. I have much pleasure, therefore, in directing your attention to some designs by an architectural friend in Berwickshire,* for whom I have written a volume upon this subject, in which you will observe, from the relative positions of the stack yard, barns, machinery, granary, straw houses, stores, &c., and the perfect isolation of the feeding cribs and courts, that the above principles are kept closely in view. The business of arranging the offices of the farm belongs to the proprietor; but it is right you should feel how the advantages and disadvantages of good and bad arrangements run. The laying out of the farm itself is a very different thing; although the size and number of fields are not always more under the tenant's control than the arrangement of the offices; his skill in farming can, nevertheless, command any extent of modification by the system of rotations he may follow.

§ 4. We have designated a farm a manufactory, and we must not forget, although but a means to an end, that one great object of its operations is the manufacture of manure. Upon this unsavoury process in farming, all profitable results depend. And yet we are

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* *Gray's Rural Architecture*, by W. W. Fyfe. £1 1s.; 50 Plates. Edinburgh: W. H. Lizars.

told, and told with truth, that in no one department of agriculture is there more culpable waste going on than here. The author of "The Muck Manual," with tears in his eyes, worthy of the pungency of his own ammonia, has on his bended knees vainly entreated the farmers to regard the dung heap as the dirty mud of California and Australia is regarded at the gold diggings. Did you ever see even *one* roofed-over manure stance? Not one. Sir Charles Napier, who ploughs the seas and not the soil, once told his fellow townsmen of Falkirk, in a speech *de omnibus reibus et quibusdem aliis*, that he was astonished to find this practice unknown in a country which boasted so proudly of agricultural pre-eminence. But the fact is that a controversy of a most conflicting character exists betwixt the advocates of short dung and long dung. Short dung is favoured by the practical men; long dung by the theorists. It is important that in a brief form, you should know "the long" and "the short" of this disputed affair, because, whilst it appears to me that short or fermented manure must necessarily be in the best digested and most favourable state for yielding off its gaseous constituents as the pabulum of growing plants,—it strikes me that I recently met with an opinion expressed by no less an authority than the Author of "The Book of the Farm" (and it is well known that Sir Humphrey Davy held the same), that the faster home-made manure can be transferred from the steading to the land, the better will its fertilising properties be conserved. Now, of the various animal, vegetable, and mineral substances that may be employed as manures, the action is sometimes diametrically opposite, putrefaction will be resisted by them in one instance, and promoted in another. Salts from the ashes of plants, the dung of fowls, that of horses in some conditions, quick lime, &c., will act in the one way; the salts found in calcareous earths, and horse litter, when rendered stimulant from the salts contained in it, will act in the other; whilst lime, after having been burnt and allowed to rest a few months, converts the putrescible matter of the soil into a gummy substance.

§ 5. In speaking of fermentation relative to manure, it must be observed that it is putrefactive; and just as *vinous* fermentation, by an extending process, renders sweet materials, such as the juices of fruits, spirituous; and the acetous fermentation, by extension of sourness, produces vinegar in liquids; so the putrefaction extends and increases putrefaction in the dungheap, which it gradually heats and converts into mucilage and salts. This last is the leading purpose to be attained, and with that view the most careful and thorough mixture of the mass is requisite to keep it in a uniform state of fermentation, and to permit no portion to precede another in reaching the stage productive of salts before the other portions have at least become mucilaginous. Thus lime, if not in very small proportion in the heap, would operate as a stimulant, and if ineffectually mixed throughout the whole would lead to the result which is to be avoided in the management of the dunghill.

§ 6. So much is heard now-a-days of guano and other artificial and imported stimulants of the soil, that persons unacquainted with the fact might be very apt to commit the egregeous mistake that farm-yard manure had ceased to be the mainstay of the farmer. It is still however his first and best, because cheapest and most natural resource; and whatever may be the excitement regarding other fertilizers they are necessarily all subordinate and merely supplementary to this in the general practice of agriculture. The value of animal manure depends, to some extent, on the food on which the animal is supported. Straw eaten without grain would acquire, for instance, little additional value as a manure in passing through the intestines, but the droppings of an animal fed on corn, pulse, rape or linseed cake seem to acquire fertility in proportion as the condition of the animal heightens. Ten loads of dung from cattle fed upon oilcake were found in Norfolk to correspond to sixteen from beasts fed on turnips.

§ 7. What it is, all these circumstances considered, that induces the farmer to throw out manure fraught with volatile principles from stables and feeding sheds, exposed to the weather, neither laid up in any regular or careful manner, secured from evaporation, nor mixed in proportions corresponding to its various qualities, common sense cannot conjecture. But unless these matters are attended to, the value of the dung must deteriorate every moment. Horse dung, especially when moist, rapidly ferments, and its components must be intimately mixed and assimilated without delay, otherwise it will give off heat and become dry and valueless; or becoming unequally decomposed grow mouldy. Retention of the natural moisture or regular and moderate wetting reduces it, however, to *spit dung* of the consistence almost of a paste; when completely decomposed as *rotten dung* it is much lessened in quantity, and in some instances proves too powerful and rapid a stimulant of plants in their first period of growth. The dung of horned cattle, naturally more moist, ferments more slowly. Its effect is also slower on the soil, although it has been always considered more durable. But when used alone it is so devoid of energy that in Essex six acres, with horse dung, were found to yield more than nine with cow dung; it is consequently for the most part formed into a compost along with the other contents of the farmyard.

§ 8. Straw, employed as litter, forms the principal ingredient of our home made manures; being trodden into dung by the weight of the animals, and acquiring value by the absorption of urine, as well as by combining with dung in various stages of decomposition; it also imparts consistence to the mass, and carries it more evenly through the processes of fermentation and putrefaction. But for the dung, the straw, on the other hand, would rot imperfectly and with difficulty. Thus both components are advantaged and the manure adapted for all descriptions of land, by the proportions of either that may be introduced, and the states in which they are. Bakewell's grand theory of converting the whole of the straw into food for his stock, believing, that, digested and passed through their bodies, it became a much more highly enriched manure, is now exploded in the principal feeding districts. Of late years much straw has indeed been chopped down, steamed, and otherwise prepared for food, or rather for admixture with food; for while a small bulk of nutritive equivalent will satisfy a large animal the means of filling and distending the stomach must also be provided. But in Berwickshire, which is supposed to stand first in feeding practice, although perhaps too exclusive a reliance on turnips is manifested in that county, the straw is not consumed to any extent as food, but almost all broken down. It is to be observed that steamed food, even potatoes, oil cake, &c., given to cattle, produces costiveness, and the dung heap being free of urine, it would be good practice, though seldom or never done, to moisten it by bringing the dry outward parts into the middle of the pile and drenching it with the drainage of the yard, carefully turning it over, breaking and mixing the lumps, and finally wetting the surface and patting it close and smooth with the shovel to keep in the heat. Excess of wet is equally, however, to be guarded against; as any part suffered to remain drenched with rain would be prevented from rotting; to prevent this the heap must not be drained but spread out evenly. Another reason for doing which is to prevent *Fire-fang* from the too highly heaped-up parts contracting excessive heat, as stable dung is particularly apt to do, when it becomes mouldy, and loses value, estimated at not less than from 50 to 75 per cent.

§ 9. It would, however, be erroneous altogether to assume that animal manure is solely dependant on the animal's food, and in no respect modified by its periods of growth and decay, as well as its condition or habit of body. You perhaps know that once in about 7 years you yourselves cease to be the same congeries of material particles which you were 7 years before. It is, as Professor Johnstone was accustomed familiarly to illustrate it in his lectures, as if there were a brick daily taken out of and replaced in a brick-building, so as entirely to change within a given time, the substance of which its fabric had been at first composed, whilst the building still retained its apparent identity. This process, which is incessantly going on in the animal frame, operates to a very different extent when the system is assimilating and stirring up matter for the enlargement of its frame, than when it is undergoing the opposite process of decay. In other words the wearing down of the system goes on as largely in the one case as in the other, without the place of that which is removed being as largely supplied. But in all cases the manure acquires largely, if not entirely, the mineral constituents of the food, which cannot be retained; and hence the chief source of its value, and the *rationale* of Liebig's maxim, "That the solid and liquid excrements of an animal are of the highest value as manure for those plants that furnish food for the animal."

§ 10. For instance: according to Boussingault's experiments:—

A HORSE

consumes		and	voids	
In 15. 0lbs. hay,	18.61ozs.	inorganic matter.	In urine,	3.51
In 5.54 „ oats,	2.46 „	„ „	In fæces,	18.36
In its drink,	0.42 „	„ „		
	21.49			21.87

A COW

In 30lbs. potatoes,	6.67	In urine,	12.29
In hay,	20.20	In fæces,	16.36
In its drink	1.60	In milk,	1.80
	28.47		30.45

Thus the inorganic constituents are restored in the proportions in which they existed in the plants used as food; and the manure of pigs fed on peas and potatoes is found, consequently, most answerable for those vegetables; that of cows fed on hay and turnips, the most valuable fertilizers for these; and night soil for promoting the growth of wheat, oats, barley, and all the cereal grasses, because man consumes more of the seeds of grain than other animals.

§ 11. Guano is, probably, the animal manure most justly in vogue in agriculture. It is a deposit formed by the large birds of the South American, African, and other tropical sea coasts, where rains do not wash out the valuable constituent salts. That which was at one time so largely abstracted from the African Island of Ichaboe that the surface was cleared off, and even the very sand (a circumstance that no doubt suggested the enormous frauds now practised in the guano trade) generally yielded from 7 to 9 per cent. of ammonia. But the best guano has always come to us from Chincha, or the Bug Islands of South America (and allow me to say that the Spanish name is by no means fanciful, as I have been told by a sea captain, engaged in this odoriferous branch of transport, that the most delightful sensation ever experienced by him in life was to get away from the bugs which swarmed about his vessel and blackened the very sails, to spend the Sunday with a brother seaman in an open boat on the open sea).

§ 12. In 1845 the importation of guano into this country was 220,000 tons, and in 1847, 82,000 tons, value half a million sterling; which it was estimated would increase our grain produce by three times the value of the importation, for, besides its leading application as a substitute in whole or in part for the usual application of farm-yard dung in raising the turnip and potato crops, guano is profitably applied as a top-dressing to the young grain crops.

§ 13. In application to the former it requires to be either covered or mixed with a quantity of soil sufficient to prevent injury to the seeds or sets from its hot causticity of character. Guano should never be mixed with any substance like quick lime, in the idea of promoting its action, which is rapid enough of itself, for the quick lime, as some of the Berwickshire farmers found soon after the introduction of guano, drives off the ammonia of the guano into the air, and its influence is lost to the plant. Neither will it act well with bones, which being slow of solution whilst the guano is quick, partial and not conjoint effects are the consequence. I remember that about 1842 or '43 so little was the nature and effects of guano understood in Scotland, that I had occasion to obtain for Mr. Laing, of Marledown, one of our most eminent turnip growers, Professor Johnston's exposition of the above fact, which then appeared a most puzzling phenomenon; and for Lord Buchan, the learned Professor's directions for the application of guano as a top dressing on lawns, where it should either be applied in a weak state of solution, or thinly sown on the eve of a copious shower, to prevent its burning the herbage. And, even now, although I see Professor Johnston had stated in his Catechism, that it is the better husbandry to use guano in raising turnips or potatoes, mixed or along with one half manure two or three cwt. guano per acre, I learned lately from the experiments of Mr. Alex. John Main, factor to Mr. Wardlaw Ramsay, at Whitehill, that as an immediate effect of guano alone, it is in the first instance superior to all other specifics for turnips or potatoes, even to the far-famed superphosphate of lime, *i.e.*, bones dissolved in sulphuric acid; and as a general rule, that simple and unmixed specifics, whether guano by itself, superphosphate by itself, or nitrate of soda by itself, are better for the special purposes to which they are generally applied than any compound yet concocted. But, gentlemen, we look, in good farming, beyond the immediate to a future result. In the whole system of things by which the human being is surrounded—from the lowest to the highest concerns that engross his mind it is the highest wisdom to do so—and thus it is that even in this peculiar matter of applying guano to gain large crops, the zealous agriculturist may err, and find too late that it is a stimulant which lasts but for a day, expends its energy, and leaves nought behind to sustain the future fertility of the soil.

§ 14. The value of animal manures consists not only in their inorganic constituents, but in their contributing to the nitrogenised principles of plants out of their large stock of ammonia. Thus the gluten of wheat, its principal nitrogenised constituent, may be increased or diminished in quantity according to the quality of the manure. A table is given by a German chemist, Hermbstaedt, illustrative of this and of the variations produced in the starch of wheat by the application of different agents, as well as of the productive results as far as respects quantity.

	Gluten.	Starch.	Produce.
Without manure	9·2 ...	66·7 ...	3-fold
With vegetable matter	9·6 ...	65·9 ...	5 „
„ cow dung	12·0 ...	62·3 ...	7 „
„ pigeon do.	12·2 ...	63·2 ...	9 „
„ horse do.	13·7 ...	61·6 ...	10 „
„ goat do.	32·9 ...	42·4 ...	12 „
„ sheep do.	32·9 ...	42·8 ...	12 „
„ dried night soil	33·1 ...	41·4 ...	14 „
„ dried ox blood	34·2 ...	41·3 ...	14 „
„ human urine	35·1 ...	39·3 ...	12 „

Thus you will perceive that as you increase your nitrogen you diminish your starch, and *vice versa*.

§ 15. What is meant by manuring with vegetable matter is the antique practice of green manuring, by ploughing-in the vegetation, so extensively practised by the Romans, who grew certain crops for no other end, though but little approved of in modern agriculture. Theoretically, green manuring ought to be more beneficial than we find it in practice. It is, however, often resorted to where the skilful farmer sees cause to augment the organic constituents. Mr. Campbell, of Craigie, a most eminent Ayrshire agriculturist, found no better way of manuring for wheat after turnips than by ploughing in the tops while still green, as soon as the turnips were taken off the land. Seaweed, which is a plant, although of marine vegetation, when applied to the land, furnishes other valuable ingredients, as carbonate, phosphate and sulphate of lime, as well as common salt.

§ 16. The result of the application of these last mentioned substances is well illustrated in an experiment performed upon pasture land near Largo, by Mr. Wilson, with hay-crop sown and reaped together, when

		Per acre.
Lot 1.	Untouched was found to yield	3360 lbs.
2.	2½ barrels fresh quick lime	4816 „
3.	20 cwt. lime from the gas works	5208 „
4.	4½ cwt. wood charcoal	5320 „
5.	2 bushels bone dust	5544 „
6.	18 lbs. nitrate of potash	5936 „
7.	20 lbs. nitrate of soda	6272 „
8.	2½ bales of soot...	6552 „
9.	28 lbs. sulphate of ammonia	6776 „
10.	— Gallons ammoniacal liquor from gas works	7560 „

§ 17. Many tables have been published and ought to be consulted for the practical inculcation of guiding principles in agriculture. I shall just adduce the systematic conclusions attained in the course of extensive practical experience by a well known authority in artificial manures—Mr. J. B. Lawes, of Deptford Creek and Roehampton.

CLASS I.

Plants Cultivated for their Primary Organs.

LEAF AND STEM.

Meadow grass, clover, cinquefoil, tares, cabbages, and other fodder plants.—*Manures :* Substances yielding ammonia rapidly, such as Peruvian guano, sulphate and muriate of ammonia, dung from stall fed cattle, salts of lime, with phosphate of ammonia, soot.

CLASS II.

Plants cultivated for their intermediate organs.

BULB OR TUBER.

Turnips, mangel wurzel.—*Manures:* Phosphate, sulphates and carbon, as, inferior sorts of guano, superphosphate of lime, well-rotted dung.

CLASS III.

Plants cultivated for their ultimate organs.

SEED.

Wheat, barley, oats, peas, beans, tares, clover seed.—*Manures:* Organic matter slowly yielding ammonia as residue from highly manured green crops, rape cake, dung from stall fed cattle.

§ 18. Professor Johnston gives the following table of results:—

Manure applied.	Returns for one bushel.			
	Wheat.	Barley.	Oats.	Rye.
Blood	14	*16	12½	14
Night soil	—	13	14½	13½
Sheep dung	12	16	14	13
Horse dung	10	13	14	11
Pigeons dung	—	10	12	9
Cow dung	7	11	16	9
Vegetable manure	3	7	13	6
Without manure	—	4	6	4

§ 19. With regard to the application of manures in an ordinary rotation, such as proposed in the second lecture of the present series:—

Course 1—Oats, the first crop in the rotation would require but little, if any, manure, if coming after previously manured green crop, lea, or as frequently happens, the breaking up of old pasture.

Course 2—Potatoes and Mangel Wurzel, in equal portions, constituting the second course, would require the one to be manured with vegetable and animal manure from the previously prepared dung-heap, at the rate of 30 to 40 tons per Scotch acre, according to the quality and condition of the soil—the other with a mixture of animal and vegetable matter, which should be applied in a well decomposed state, at the same rate of 30 or 40 tons per acre.

Course 3—Wheat, the culture of which, after the fallow, crops of potatoes and mangel wurzel, is a simple process, and for manure would be, as before, principally dependent on the residue from these and other additions slowly yielding ammonia.

Course 4—Turnips, Carrots, &c. The land is to be limed at the rate of 30 bolls of shells per acre, after removal of the wheat crops; lime, though an important agent in increasing the fertility of the soil by calling into action its nutritive principles and greatly improving the quality of produce, must, nevertheless, be employed in moderation, since overdoses, such as we see too often laid down, inevitably occasion scourging crops and ultimate barrenness. The quantity here given is to be applied only once in the six-shift rotation, and in this manner—the lime shells may be carted to the farm during summer and there mixed with an equal bulk of earthy matter, couch grass, or other weeds apt to decompose; road scrapings, ditch scourings, the earth and root fibres of headlands and old hedge-rows that may have been levelled—everything adds to the variety, and there is good in everything—besides, this slight mixture is of easier application to the land than a mere earth mixture—the extraneous matters are always beneficial, and the lime thus mixed is more easily managed, particularly should the weather be windy. Lime, when applied on stubbles, is generally ploughed down with a light furrow.

This, however, is not manuring for turnips or carrots. It is an amelioration of the land for the ensuing rotation. Turnips are to be manured from the previously prepared and well decomposed heap, at the rate of 30 tons for Swedish, and 25 for other descriptions, laid in heaps in the hollow of every fifth drill at 9 feet intervals, and then spread equally in the hollows of all the five drills with light three-pronged forks, so as to be immediately covered in by the double mould-board plough, when splitting the drills down their centre, as described on a former occasion. Carrots may be manured with 30 tons farm yard dung, laid on the stubbles and ploughed in as fast as ever it is carted out and spread, to prevent evaporation of its essences. This is all without going beyond the farm itself for an accession of manure.

Course 5—Barley. By harrowing across the firmer drills of green or root crops, as explained before, a rich soil is diffused over the undunged intervals and assists materially the production of barley, whose success, like that of common grass-seeds, depends more on pulverization than the immediate application of manure.

Course 6—Grass, for soiling and hay, having been sown down with the barley, may be depastured whilst young by sheep, whose "golden feet," as the farmer calls them, will tend to its enrichment, whilst cattle in general would poach and destroy the young plants, and even sheep must not be suffered to crop the herbage too bare, since, if stinted for food they will eat the crown spike of the young plants, and destroy its vitality.

§ 20. It has been seen that our schemes of farm offices are provided with tanks to receive and collect the liquid manure from the byres, stables, and yards. The contents of these tanks are principally to be used for the grass lands. The English implement makers for this purpose have extensively introduced liquid manure drills; but where these are unemployed one or two large barrels may be mounted on frames or wheels, having an apparatus (a perforated tube, &c.,) attached behind the barrels for spreading the liquid evenly on the land; and if each of these are made to cover 9 feet, two turns will thus cover the 18 feet ridge. These liquid manure carts put in requisition as early in spring as the dryness of the land will permit (for the earlier the more valuable to grass), are to be continued until a complete soaking has been bestowed on the whole grass land—and even a second, if liquid enough remains, and the crop not too far advanced; by this means a soiling crop may be cut early in May. The mowing should be succeeded by a daily application of liquid manure to bring away the next crop, and in this manner a succession of rich cutting grass may be insured throughout the summer. A double portion of liquid must be applied to any portion of the crop intended for hay, as this portion will more exhaust the land than that cut for soiling. Look at the foul water irrigation now so successfully employed round Edinburgh, Milan, &c. What is it but minute manuring by the fertilising particles collected in the town streets, floated on to and diffused throughout the vegetation once bare and scanty of the celebrated Figgatewhins and dear at half-a-crown an acre, now yielding rents of £20, and even £30 an acre, in consequence of the luxuriant crops of rich, early, though rank and coarse, grass grown on the once desert waste. At Milan, Florence, Grenoble, and other foreign cities the same plan is pursued with the same success, placing beyond a doubt the enriching character of the system of liquid manuring. Liquid manure must be diluted in the very tank to preclude putrescence. The application of the ammoniacal liquor of the gas works is, as we have seen, a fertile application of a liquid kind. It requires to be diluted with five times its bulk of water.

§ 21. It would be impossible, however, to do justice to the existing agricultural system in its present state of advancement without at least naming the advantages of the artificial agents on which so much is now expended in farming.

§ 22. Phosphate of Lime, a white earthy substance composed of lime and phosphoric acid, occurs abundantly in the geological formations of North America, and is dug up and sold under the denomination of bone earth in the *green sand* or *crag* of England to be used for agricultural purposes—the discovery of these phosphate beds being reckoned one of the most important benefits science has lately conferred on agriculture. When ground into powder this mineral phosphate is dissolved like bones in sulphuric acid, and applied to corn and root crops under the same name acquired by dissolved bones when thus prepared, viz., superphosphate of lime.

§ 23. Nitrate of Soda, a white saline substance found in Peru, is applicable as a top-dressing to grass lands and young corn. It is frequently adulterated with common salt, which, however, crackles, whilst nitrate of soda, as well as nitrate of potash (saltpetre) simply flare, if a pinch be thrown into a hot fire; and thus the adulteration may be detected. Nitrate of soda is composed of nitric acid and soda in the proportions of 54 to 31, and is valuable in supplying nitrogen and soda to growing crops, applied in spring as a top-dressing, 1 to 1½ cwt. per acre.

§ 24. Sulphate of Soda or Glauber Salts is composed of sulphuric acid (vitriol) and soda in the proportions of 40 to 31, and is beneficial as a top-dressing for grass, turnips, beans, and young potato plants.

§ 25. Sulphate of Magnesia or Epsom Salts consists of 84 of magnesia, and 66 of sulphuric acid.

§ 26. Sulphate of Ammonia, 23½ of ammonia to 53½ of acid, is also applied profitably to young grain crops in spring.

§ 27. Common Salt, 60 of chlorine and 40 of sodium, and therefore chloride of sodium, exists in all cultivated crops, especially roots, such as turnips and mangel wurzel, and is therefore necessary to them, especially in places remote from the sea or screened from the sea winds by hills. The usual influence of the sea spray is said to extend in-shore through seven miles of atmosphere, although in sea storms, leaves, in the direction of the wind, have been found covered with salt crystals 20 miles from the sea. Applied as a top-dressing to grain crops it almost invariably increases the weight per bushel of reaped grain, and it is advantageous to mix it with the farm-yard manure, or the water employed in slaking lime.

§ 28. Gypsum, 40 of sulphuric acid to 28½ of lime, is sulphate of lime, plaster of Paris—stucco—forming a valuable top-dressing for red clover and leguminous crops. Its great value, if properly appreciated, would, however, be found in strewing it in a moist state over fermenting dung heaps and stable floors, in order to fix or retain the ammonia by converting the volatile carbonate into the less volatile sulphate of ammonia. 100lbs. of burnt gypsum would fix as much ammonia in the soil as 6,250lbs. of horses' urine would yield to it. Its action also is not instantaneous but lasts for years. It is recommended to use these saline substances in calm weather, and like guano, to take care they be applied before or soon after rain, so as to become dissolved in the soil. A mixture of nitrate and sulphate of soda is also said to act more beneficially on the potato crop than either alone; and a mixture of common salt and gypsum in like manner on the bean crop.

§ 29. Facts and practical experience thus inform us that in the growth and nutrition of plants *carbon* and *nitrogen*, from the atmosphere, are the first elements essential to the growing structure; *oxygen* and *hydrogen*, besides other matters adventitiously furnished by water, the next; and finally come in the saline, earthy, metallic, and other constituents supplied by the soil. Thus air, water, or earth contributes each its quota. This branch of phytology, or the general study of plants, has been involved in considerable misapprehension and obscurity by suppositions (for they are no better) based on the presence and action of a vegetable humus—as the immediate agent of the nutrition of plants. One great difficulty has been the existence of carbonic acid in the atmosphere in the proportion of only one gallon in 2,500. But how beautiful is that provision of nature which has hung out over the forest foliage myriads of feeders in the shape of leaves, to supply its gigantic trunks with their voluminous bulk out of this sparingly diffused material; and how admirable the atmospheric mechanism which so seconds the process that every breath of wind brings a fresh mouthful of food to the carbon-eating leaflet! Nor is it the vast extent of surface thus exposed to the act of carbon-seeking by vegetation—an extent which may be more easily conjectured than expressed when we find it estimated that a single oak exhibits seven millions of its leafy bannerets to the winds; but it is still more astounding to count, by the aid of the microscope, the multitudinous mouths with which each inch of this multiform surface is endowed under the designation of stomates—literally mouths. These are generally more abundant on the under than the upper side of the leaf. But on a single square inch the

Vine	has on the upper side	none	under	13,600
Rhubarb	„ „	1000	„	40,000
Lilac	„ „	none	„	160,000
Cherry Laurel.	„ „	none	„	90,000
Mistletoe	„ „	200	„	200
Olive	„ „	none	„	57,600
Holly............	„ „	none	„	63,600
Clove Pink	„ „	38,500	„	38,500

The oxygen extracted from the atmosphere by every coal fire and every animal respiration is replaced in volume by the same bulk of carbonic acid. Vegetable life absorbs the carbonic acid in turn, and restores the oxygen during the day—but not at night, for plants then give off carbonic acid. But so it is that the balance of proportion is accurately maintained in the great laboratory of the atmosphere. The composition of the atmosphere notwithstanding these changes continues invariably the same. The acre of land which produces 8 cwt. of carbon, in the shape of woody fibre, gives annually to the atmosphere 2,600lbs. of free oxygen gas, and therefore replaces in the atmosphere as much oxygen as is exhausted by 8 cwt. of carbon, either in destructive combustion or the action of animal lungs. Plants purify the air of matter noxious to animals. Animals throw off from their lungs carbon, nutritious to plants. Thus they keep up a constant interchange of relative proportion in their vital elements.

§ 30. There is some extent of this very element of carbonic acid of which the bodies of plants are built up, however not derived from the atmosphere. Trees, for instance, when destitute of leaves, cannot extract food from the atmosphere. But the leaves which had strewn the forest in autumn—the old roots of the meadow-grass —are converted by the agency of decay into a vegetable humus—forming in every fertile soil an atmosphere of carbonic acid, the first and most important food of young plants ere they reach the surface. It was on a knowledge of this fact that Liebig based his dictum—"If the end of cultivation, viz.: the production of the largest amount of perfect growth in the shortest time is to be obtained, we must create in the soil an artificial atmosphere of carbonic acid (and ammonia) and this surplus of nourishment must be taken up by the roots." This vegetable mould must, however, be exposed to air ere the seeds will germinate; seeds not fully supplied with air, but coated with matter which the air cannot get at, produce weak and diseased plants; hence the philosophy of ploughing—of mechanically tearing up, dividing and tilling the soil. The roots in early stages perform the functions afterwards taken up by the leaves, extracting the carbonic acid generated in the soil, but on the matured plant obtaining its food from the air the carbonic acid of the soil is no longer required. Even when the whole woody fibre has been elaborated, the action of the leaf does not cease—carbon is still absorbed. But the leaves now produce sugar, starch, gum, or acids,—throw them off into blossoms—ripen them into fruit—till, yielding to the chemical influence of the oxygen of the air, they change colour and lose vitality—their functions are fulfilled.

§ 31. The hydrogen necessary to the formation of plants, they derive from the decomposition of water. Nitrogen, which exists in every part of the vegetable structure, is derived from the ammonia of the atmosphere—of which nitrogen is a constituent—washed down to the roots by rains; or, in the case of corn, artificially conveyed to the roots in the form of soluble salts of ammonia, derived perhaps from animal putrefaction. Of the sources of nitrogen there is no lack amidst this world's frightful mortality.

§ 32. In the item of human beings alone a generation of a thousand millions, not to mention countless millions of the lower animals, fall every thirty years. The gases from this hideous mass of decomposition pass into the air; rain water thus at all times contains ammonia. If one pint of it contained only a single grain, a field of 40,000 square feet would receive annually more than 80lbs. of ammonia, equivalent to 65lbs. of nitrogen—the annual fall of rainwater on that extent of surface being 2,500,000lbs.—much more nitrogen than exists in the vegetable albumen and gluten of 2,650lbs. wood, 2,800lbs. hay, or 10 tons of beet root, the yearly produce of such a field. But, from cultivation and manuring, the straw, roots, and grain of corn reared on the said surface might be and practically are made to contain more nitrogen—such being the *rationale* of fertilizing the soil.

§ 33. We have, therefore, in the rational view of agriculture we seek to develop, arrived at three conclusions: 1st—That heat, light, moisture, and the common elements of the atmosphere are necessary to afford plants mere existence. 2nd—That certain fertilizers, already contained in the soil, or suppliable, as manure, are found to exercise a specific influence over the development of plants, in whole or in part; and 3rdly—

§ 34. That we may succeed in imparting to each plant exactly what is required to promote the purpose for which we grow it, that is, an artificial increase of the particular parts we value. Thus, in the cultivation of flax, in which our ordinary agriculturists are so much perplexed after the lapse of a whole generation since it was grown amongst us, science at once informs us that we must pursue, in order to produce its fine pliable straw or fibre, the very opposite course from that which is proper for producing the largest possible quantity of corn, yea, or the best linseed from the flax itself.

§ 35. The same law obtains in the fattening of animals. Wild animals are lean. We can fatten domestic animals artificially. We can lay on flesh and fat by adding to the quantity of food consumed, and lessening the waste from increased respiration caused by motion and muscular exertion acting on the skin.

§ 36. With regard to the comparative values of agricultural products, two circular tables, which have been got up in illustration of this matter, indicate with peculiar force the advantages and disadvantages attending the culture of particular crops. The one table shews the equivalent weight of one description of nutriment as contrasted with another. It is provided with a revolving index, which being set at the description of food the equivalents for which are demanded—shews the equivalents to the right. Thus, if set at beans, it will be found that 112lbs. beans are equivalent to 104·926lbs. wheat, 108·348 barley, 113·273 rice, 125·859 oil-cake, the same of rye, 134·340 oats, 383·384 potatoes, 673·513 mangel wurzel, 1017·143 carrots, 1365·481 cabbage, 2378·333 turnips. The other table shews the value or the price which the several descriptions of food stated in the index should command, according to the comparative nutriment of wheat taken as the standard. Thus, if wheat is at 45s. per quarter—butcher-meat, which is not stated, however, according to its comparative nutriment, but at the price at which 14 lbs. could be raised when wheat is at a certain value, is worth 5·526s. per stone, turnips 8·842 per ton, cabbage 15·368, carrots 20·631, mangel wurzel 31·158, potatoes 54·733, oats 22·315 for 320 lbs., rye 31·262 for 240lbs., oil-cake 166·733 per ton, rice 185·262 per ton, beans 42·158 per 504 lbs., barley 36·315 per 420 lbs., dry pease 44·052 per 504lbs.; these being the proportions in which the articles are sold.

Incidental Questions.

1. Mention generally the purport of the preceding lectures?

2. What means may be suggested for best imparting agricultural knowledge?

3. How might the object be promoted by premiums, and for what should they be offered?

4. Would it be easy or advantageous to arrange instructive farm excursions, and how?

5. Has this ever been practically proposed in connection with any chair of agriculture, and what analogous excursions exist?

6. What elements are comprised in the present lectures favourable to their adoption as a class book?

7. State then the portion of this ground over which we have travelled, and what now remains?

8. What is the most practical view of a farm?

9. How is it to be conducted as a vegetable manufactory?

10. How as a manufactory of animal produce?

11. Why is the subject of *Farm Steadings* growing in importance?

12. Mention the way in which the principles of arrangement are kept in view in *Gray's Rural Architecture?*

13. Is the business of arrangement that of the tenant or proprietor?

14. Why may the tenant be said to have more influence over the out-door arrangements?

15. Upon the manufacture of what intermediate product does the profit of farming depend?

16. Yet is there not waste here?

17. Arising chiefly from what?

18. What is the nature of the contest betwixt short dung and long dung?

19. Give instances of opposite action in manurial substances?

20. What is the nature of the fermentation of dung?

21. What process is requisite to produce uniform fermentation?

22. Describe the result of neglecting it?

23. What reliance is to be placed on farm-yard manure?

24. On what does the value of animal manure somewhat depend?

25. Exemplify results from straw eaten without grain, as contrasted with richer feeding?

26. In Norfolk, what ratio is assigned to dung from oil-cake, as compared with turnip feeding?

27. Is dung, then, deteriorated by exposure to the weather?

28. More particularly, as regards horse dung, what ensues?

29. How is it to be converted, however, into *spit dung?* and what is *spit dung?*

30. And how into *rotten dung,* and in what condition is this last?

31. What may be observed respecting the dung of horned cattle?

32. In Essex, what ratio is assigned to horse as compared with cow-dung?

33. And how is horse-dung usually applied?

34. How is straw employed in dung-making? and what are its effects?

35. What was Bakewell's theory of the conversion of straw, and is it now maintained or not?

36. How has straw of late years, however, been employed in the economy of food?

37. In Berwickshire, with its high-feeding reputation, is straw, however, employed as food, or broken down?

38. What effect does steamed food produce in cattle?

39. What practice now omitted might, therefore, prove advantageous?

40. What results, however, from drenching the heap, and how is drenching remedied?

41. How is fire-fang prevented, and what per centage of loss arises from it?

42. What else besides food may modify the value of animal manure?

43. How often is the animal frame said to change its material particles?

44. What becomes of the mineral constituents, and what maxim of Liebig is founded on this?

45. Quote the figures contained in Boussingault's experiments regarding the consumption and voidance of the horse and cow?

46. What inference may be drawn from this respecting the restoration of the organic constituents?

47. For what uses would the manure of pigs seem best adapted, and why?

48. For what that of cows, and why?

49. For what night-soil and why?

50. What is guano?

51. What happened at the Island of Ichaboe?

52. What per centage of ammonia was yielded by Ichaboe guano?

53. Whence is the best guano obtained? And what is the origin of the name of these islands?

54. Mention some of the figures connected with guano importations.

55. What rate of increase is it estimated that guano will produce in value on our produce? and why?

56. How should it be applied?

57. What results from its intermixture with active or slow substances? Mention examples.

58. What conclusion has Mr. Main drawn regarding pure and compound specifics?

59. Is there any danger of guano proving but a momentary stimulant?

60. What is the real test of value in animalised manures?

61. May the gluten of wheat be increased or diminished? And by what means?

62. What does Hermbstaedt's table illustrate? and can you repeat any of the figures?

63. State generally what is perceptible in regard to the increase and diminution of this table.

64. What is the antique practice of green manuring? By whom practised, and what modern instance may be quoted? Is the practice of applying seaweed analogous to this?

65. Give particulars of application of different substances by Mr. Wilson, of Largo.

66. Outline the systematic conclusions of Mr. J. B. Lawes.

67. What results are given by Professor Johnston?

68. Repeat the conditions of manuring requisite for the six-course rotation?

69. Why do the oats in the first course require but little manure?

70. What proportions are required by the potatoes and mangel in the second?

71. On what would the wheat in the third course be chiefly dependant?

72. State the effects of liming for the 4th course of turnips, &c.

73. State also the proper mode of manuring for it.

74. In the fifth or barley course, what effect is produced by harrowing across the former drills?

75. Mention the effects of depasturing the sixth (grass) course, as respects animal droppings, &c.

76. Are tanks and liquid manure implements now much used?

77. How may rude substitutes be provided for the latter?

78. State the mode of application and manuring.

79. What famous instances of foul water irrigation can be given?

80. Must liquid manure be diluted even in the tank? and why?

81. Is the ammoniacal liquor of gas works available, and how much must it be diluted?

82. Name the principal artificial agents now generally available in agriculture.

83. What is phosphate of lime, and how is it prepared and applied?

84. State the facts connected with nitrate of soda?

85. What is sulphate of soda, and for what beneficial?

86. What is sulphate of magnesia?

87. What is sulphate of ammonia, and for what is it profitable?

88. Does common salt exist in all crops, and in any part more particularly?

89. How far does the influence of the sea spray extend inwards?

90. State the effects of salt, applied as a top-dressing to grain crops?

91. What is gypsum? and what its value as a top-dressing?

92. How might it be rendered still more rich as a fixer of ammonia?

93. State a comparison betwixt the amount of ammonia "fixed" by 100lbs. of gypsum and that yielded by horses' urine.

94. Is its action instantaneous or enduring?

95. What recommendations are to be attended to in using agricultural salts?

96. What essential elements of plants then appear to be furnished from the atmosphere?

97. What from water?

98. What from the earth?

99. What has been said regarding "humus?"

100. How is carbonic acid diffused in the atmosphere?

101. What provision of nature seems intended to multiply the means of access to it in vegetation?

102. How many million leaves may a single oak possess?

103. Where are the mouths or stomates of leaves situated, and how many do certain leaves of plants have per square inch?

104. Is the oxygen of the atmosphere consumed by fire, replaced bulk for bulk in the atmosphere, and by what?

105. What in turn absorbs the carbonic acid?

106. And does the general composition of the atmosphere continue quite the same amidst these changes?

107. What functions of plants and animals then are useful to each other, and how?

108. Do plants derive carbonic acid from any other source, and how?

109. What dictum of Liebig is based on this?

110. Does vegetable mould or humus require exposure to the air ere plants will vegetate in it?

111. What happens to seeds not supplied with air?

112. What operation in agriculture does this suggest?

113. When does the plant cease to require the carbonic acid of the soil?

114. When the woody fibre has been elaborated, what do the leaves then form out of the carbon?

115. Whence do plants receive hydrogen?

116. Whence nitrogen? and how?

117. Is it ever artificially applied?

118. Is there any lack of it in the world?

119. How many men fall every 30 years, besides countless animals?

120. What becomes of the gases of decomposition?

121. What three conclusions may be called the *rationale* of agriculture?

122. Does the same law obtain in the fattening of animals as in the growth of plants? Explain.

123. How would you propose readily forming a revolving index of the equivalents in weight and value of different kinds of nutriment?

124. How of the value that ought to be commanded by each class of nutriment, when the price of wheat is taken as the standard?

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